THE POLITICAL ECONOMY OF EPIDEMIOLOGY

by

Byron Carson
A Dissertation
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The Requirements for the Degree
of
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Committee:

_____ Director

_____

_____

_____ Department Chairperson

_____ Program Director

_____ Dean, College of Humanities and Social Sciences

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Byron Carson
Master of Arts
George Mason University, 2013
Bachelors of Arts
Rhodes College, 2011

Director: Christopher Coyne, Professor
Department of Economics

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Fairfax, VA

DEDICATION

This work is dedicated to my loving family: Barbara Carson, Byron Carson, and Helen Carson.

I will always be inspired by their love and support.

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ABSTRACT

THE POLITICAL ECONOMY OF EPIDEMIOLOGY

Byron Carson, Ph.D.

George Mason University, 2017

Dissertation Director: Dr. Christopher Coyne

These essays develop an institutional framework to epidemiology that highlights the conditions under which private actors resolve collective action problems associated with the prevention of infectious diseases. This framework is applied to a number of historical and modern cases from the United States and across the world to show that despite the theoretical problems of externalities and free riding, private coordination is more likely than previously thought. This is the case when people can capture the benefits of prevention and lower the cost of coordination. The main conclusion is that private and alternative disease prevention can be important means of mitigating the burden of infectious diseases, especially when people do not have access to functional governmental health institutions.

This first essay reviews the economic literature on epidemiology, explores the collective action problem people face in response to disease prevention, and highlights the diverse formal and informal institutions that encourage preventative behavior. A variety of formal and informal institutions, as well as the bio-medical and

epidemiological characteristics of particular infectious diseases, can help resolve collective action problems associated with disease prevention, in theory and in reality. The incentives people face within private sector firms, as a result of liability law, and from informal norms shows that people can coordinate the prevention of diseases like Malaria, Ebola, Plague, and HIV. Public health policy and government interventions become one of the many ways people can coordinate the prevention of infectious diseases. In this view, economic analysis of epidemiology can incorporate diverse human interactions in response to epidemic disasters, from entrepreneurship and the formation of a firm, to liability law and informal norms.

The second essay explains how a railroad company in Texas and cotton mills in North Carolina successfully prevented malaria in the early twentieth century in the absence of capable government services. Focus is placed on the incentives these firms faced to privately coordinate malaria prevention during this time but not after. These firms, motivated by potential productivity improvements and profit opportunities, implemented extensive anti-malaria programs and used their hierarchical organizational structures to monitor performance. The factors underlying the decline of private prevention include a fall in the overall rate of malaria, the increasing presence of the federal government, and technological innovations that lowered exposure to mosquitos. Understanding how, why, and when firms can prevent diseases has important implications for current disease policy, especially where governments, international organizations, and technologies are not enough.

The final essay explains why large concession firms in Liberia helped to prevent Ebola during the 2014-2015 epidemic. Primarily, these firms held better defined and enforced property rights relative to smaller firms and individual Liberians. With such rights, the owners of larger firms have more of an incentive to care for the health and safety of their workers, as well as their dependents and local communities. To assess the role property rights have, concession agreements are analyzed for the largest Liberian firms in agriculture, mining, and oil and gas. 11 of the concessions actively responded to the epidemic, and most reported zero cases of infection; about half of the largest, relevant concessions in Liberia were responsive. 10 of the largest concessions were unresponsive for reasons unrelated to the epidemic, while information was not available for 9 of the concessions. As an industry, agricultural concessions were more responsive as 7 of the 11 agricultural concessions responded, whereas 3 of the 15 mining concessions responded. Additional factors like the relative scarcity of labor and public health alternatives are also considered. Thus, one of the main implications is that property rights, in the form of concession agreements, are an important factor in explaining why large Liberian firms faced incentives to prevent Ebola.

CHAPTER ONE

…it seems that epidemiology is an area where economics as a social science may successfully compete with other approaches, coming out of the natural sciences. Despite its recent growth, the field of economic epidemiology remains in its infancy relative to its possibilities. The global importance of world-wide mortality caused by infectious disease ensures that such research will pay valuable dividends by improving the understanding of the way infectious diseases spread, and the ways individuals and institutions can control them. (Philipson 2000: 1797)

I Introduction

The control and prevention of infectious diseases emits external effects through a lower probability of infection and gives rise to free riding and collective action problems (Buchanan, 1964; Tullock, 1969; Gersovitz and Hammer, 2003, 2004, 2005). By taxing infectious behavior or subsidizing preventative behavior, governments coordinate preventative action when individuals are not capable of doing so. This is especially the case when governments are assumed to be omniscient and benevolent (Brito, Sheshinski, and Intriligator, 1991; Avery et al, 1995; Geoffard and Philipson, 1997; Francis, 1997 and 2004; Mechoulan, 2007; Althouse et al., 2010; Fenichel, 2013; Chen and Toxvaerd, 2014). Indeed, local governments established checkpoints and quarantine stations throughout medieval Europe to contain plague (Alfani and Murphy, 2017). In the United States, the Constitution of the United States encouraged the spread of infectious diseases by spurring population growth and by raising the cost of forming public health agencies (Troesken, 2015); and the Bureau of Animal Industry controlled various livestock

diseases in America beginning in the late nineteenth century (Olmstead and Rhode 2015). International governmental coordination eradicated smallpox in the middle of the twentieth century (Barret, 2004, 2007; Barret and Hoel, 2007).

Yet, governments face knowledge and incentive problems that limit the provision of health care and disease prevention.[1] Functioning governments often collect vital statistics like mortality rates, but others lack the ability to maintain a vital registration system or good census data, a 'scandal of invisibility' (Setel et al., 2007; Deaton, 2013: 187). Public funds for health may be insufficient especially as politicians and bureaucrats have competing goals and interests (Ryan, 2014; March, 2016) and as rates of non-communicable diseases raise health costs (WHO, 2010).[2] Absenteeism limits the effectiveness of publicly provided health care, especially in India (Banerjee, Duflo, and Glennerster, 2008). Related to disease prevention, mission creep limits the effectiveness of public health surveillance (Mariner, 2007). Many governments have banned the use of DDT, an effective anti-mosquito poison, because of its environmental costs (Bate, 2000). The broad nature of public health (Rothstein, 2009) and the ever-changing nature of infectious diseases (Cohen, 2000) suggest that public officials may be ill-equipped to respond to outbreaks and epidemics.

Given the tensions between governmental coordination in theory and in practice, people may choose alternative institutions to resolve collective action problems

[1] According to the Fund for Peace's Fragile States Index, 38 countries are fragile states, which are the states most at risk of collapse. For theoretical reasons on why governments are generally dysfunctional, see Keech and Munger (2015).

[2] On the perverse incentives of the World Health Organization, see Tollison and Wagner (1993).

associated with disease prevention.[3] Following Ostrom (2005: 3), institutions are prescriptions that humans use to organize repetitive and structured interactions. This paper shows how institutions like private sector firms, liability laws, and informal norms alter the costs and benefits of preventative and infectious behavior. Malaria prevention in the United States and in sub-Saharan Africa during the 20th century, Ebola prevention in Liberia during the 2014 epidemic, and the HIV epidemic in the United States demonstrate how these institutions establish incentives to encourage preventative behavior. Appendix I shows how large these epidemiological events were and their geographic distribution.

The analysis herein makes a number of contributions to economics, development, and public health. Economists have elaborated a rich understanding of how formal and informal institutions influence economic, political, and social activity (Ostrom, 1986; North, 1990; Rodrik et al, 2004; Hodgson, 2006; Williamson, 2009; Boettke and Coyne, 2009; Boettke and Leeson, 2009; and Storr, 2013), but the application of these insights to a classic public good like disease prevention has been underexplored. This is surprising, perhaps, as there is a growing number of theoretical, historical, and experimental studies showing how private actors resolve problems related to externalities and free riding (Ostrom, 1990, 2005; Sandler, 1993; Lichbach, 1994; Sandler, 2015) so as to facilitate the provision of public goods (Anderson and Hill, 2004; Beito et al., 2009; Bogart, 2005; Brubaker, 1975; Coase, 1974; Cheung, 1973; Cornes and Sandler, 1996; Demsetz, 1970; Foldvary, 1994; Harrison and Hirshleifer, 1989; Klein, 1990; Smith, 1980; Skarbek,

[3] Choices favoring alternative institutions of disease prevention are similar to choices of living without government. Indeed, Leeson (2006) shows the conditions under which people choose to live under anarchy and provides a number of case studies where people are better off without formal governance (also, see, Leeson, 2007; Leeson and Williamson, 2009; Leeson, 2014). For a survey on public choice and the economic analysis of anarchy, see Powell and Stringham (2009).

2014). Exceptions include studies of how firms in the private sector face financial incentives to prevent diseases: coal-mining firms provide sanitation services in the United States (Fishback, 1992), cotton mills and railroads provide mosquito elimination services in the southern United States (Carson, 2016), and large agricultural and mining firms provide care for HIV patients and prevent further infection in sub-Saharan Africa (Bloom et al., 2007). As the head quote suggests institutional analysis can provide a unique framework to understand how people coordinate scarce resources to prevent infectious diseases (Philipson, 2000); indeed, as issues arise from uncertainty and complexity, institutional analysis relative to the neoclassical approach to health economics is a more relevant framework to understand health outcomes (Hodgson, 2008).

An institutional approach to epidemiology also expands the notion of prevalence elasticity, a foundational concept in the economic literature on epidemiology (Philipson, 2000; Roberts, 2006; Laxminarayan and Malani, 2011). The general implication of prevalence elasticity is that the spread of infectious diseases is limited by the extent to which people voluntarily change potentially infectious behaviors (Posner and Philipson, 1993; Ahituv et al., 1996; Goldstein et at, 1996; and Oster, 2016).[4] It is not always clear, however, whether people are responsive, how they respond, and the magnitude of that response. People with a higher time preference may be less responsive (Kremer, 1996; Oster, 2012), and social factors like power relationships, inequality, and stigma may deter

[4] For example, as the prevalence of HIV increases, the cost of potentially infectious behavior rises, and people substitute away from behaviors that may lead to infection, e.g., unsafe sex, having many sexual partners, and exchanging unhygienic needles.

responsiveness, especially in reference to HIV (Johnston, 2013). That institutions influence the magnitude and kind of responsiveness rarely is discussed.

Finally, studying the institutions of disease prevention develops novel channels through which human behaviors influence well-being and economic development. Infectious diseases can lower worker productivity, reduce investments in human and physical capital, and encourage social discord (Bloom and Sachs, 1998; Gallup and Sachs, 2001; Lopez-Casasnovas, Rivera, Currais, 2005; Madsen, 2016), but these burdens may be endogenous and their effect on development may be overstated (Young, 2005; McGuire and Coelho, 2011; Datta and Reimer, 2013). Indeed, political and economic institutions explain much of the cross-country differences in growth rates due to the incentives people face to engage in valuable economic activity (Acemoglu, Johnson, and Robinson, 2003; Acemoglu and Johnson, 2007; Bloom et al., 2014; Acemoglu and Johnson, 2014). Bhattacharyya (2009) develops a unifying approach suggesting that diseases are more prevalent when institutions are weak, i.e., in earlier periods of growth. The institutions of disease prevention illuminates how people respond to health threats in order to lessen the burden of infectious diseases. Furthermore, that institutions influence preventative behavior suggests institutions have more of an influence on economic development.

II The Collective Action Problem of Disease Prevention

The fundamental economic problem of disease prevention is commonly modeled as a collective action (CA) problem whereby prevention is complex and prohibitively

costly for individuals to provide on their own. The well-known free rider problem poses the core of this problem (Olson, 1965; Tullock, 1969), which leads to an under provision of disease prevention. Individuals benefit from the preventative behaviors of others and are better off by decreasing their preventative behavior, especially when prevention is privately costly. Some individuals may derive enough benefit from preventative behavior, such that prevention will be provided, but the external effects remain (Cuyler, 1971; Bloom and Sevilla, 2005; Smith and MacKellar, 2007). A group with such individuals are known as a privileged group (Olson, 1965: 49).

To discuss a variety of preventative behaviors, the collective good of prevention is denoted as a prevention campaign, which is thought of as any effort to change the status of a person(s) from being susceptible to an infection to being non-susceptible. Prevention campaigns encompass the goals of prevention, containment, and elimination. Examples include, but are not limited to, draining swampland to eliminate mosquitos, providing clean water, and wearing condoms during risky sexual activity.[5] As people invest in a prevention campaign, the immediate effect is the campaign is more likely to reduce the probability of infection. Individual contributions are made until the marginal private benefit of prevention equals its marginal private cost. As the external effects of prevention rise, however, the intermediate effect is that free riders emerge, and individual contributions fall. The prevention campaign, with fewer and fewer contributions, has a smaller impact on the prevalence rate of an infectious disease.

[5] Eradication is a kind of prevention campaign, but is ignored below as it is a special case wherein the CA problem is most severe. Indeed, smallpox remains the only infectious disease to be eradicated, primarily due to a subset of privileged countries that valued the collective good of eradication more than the costs (Barret, 2007; Barret, 2004; Barret and Hoel, 2007).

In general, free riding is a likely outcome when people expect to interact with others a finite number of times, when communication is costly, when people prefer present over future consumption, and when preferences are heterogeneous (Leeson, 2008).[6] This is especially the case in the context of disease prevention as communication may be difficult in the chaos of a disease outbreak or epidemic, and discount rates may be high as people face greater chances of illness and death. Thus, the analytic challenge of resolving the CA problem of disease prevention is to transform a non-cooperative outcome into a cooperative one, which encourages an effective prevention campaign.

Institutions transform this situation by establishing incentives that reward preventative behavior and punish infectious behavior, similar to a selective incentive (Olson, 1962; Sandler, 1992). Organizations and formal and informal institutions impose different incentives, which have different effects on behavior. While government coordination is one way to alter the incentive people have to prevent infectious diseases, alternative institutions like firms in the private sector, liability laws, and informal norms accomplish similar objectives. Each of these institutions and their influence on prevention campaigns are discussed below.

III Entrepreneurship as a Means of Disease Prevention

To be a relevant means of disease prevention, the owners and managers of a firm or other organizations must be entrepreneurial when it comes to implementing a

[6] Leeson (2008) shows how conflict can be transformed into coordination by applying the insights of Tullock's work on non-human societies to human societies.

prevention campaign.[7] As entrepreneurs have financial incentives to ensure the health and welfare of employees and customers, they can invest in technologies to control and prevent the spread of infectious diseases. These technologies include the scientific tools of prevention, as well as the organizational arrangements that potentially mitigate collective action problems within a firm. The latter technologies are particularly important as agency and monitoring problems arise (see, for example, Barzel, 1997). Indeed, the ultimate output of prevention, i.e., a fall in the prevalence rate of a disease, may be difficult to observe; this is especially the case for diseases with longer incubation periods or for diseases with obscure modes of transmission. Two primary organizational technologies for prevention campaigns include tying collective and private goods (Klein, 1987) and the formation of firm-specific health departments whose primary goal is to monitor the prevalence of a disease.

Tying represents an entrepreneurial solution to the CA problem of disease prevention because the owners and managers of a firm and other organizations must decide which goods to tie, how to acquire property rights over those goods, and how those goods will be sold. For example, the benefit of prevention can be contingent on the purchase of land, on employment status with a firm, or on membership with other non-profit organizations. The extent to which tied goods resolve the collective action problem depends on the degree of complementarity between the collective and non-collective

[7] The economic, political, and social institutions that influence entrepreneurship in general (Boettke and Coyne, 2009; Leeson and Boettke, 2009) may be important determinants of whether individuals have incentives to coordinate preventative behaviors.

goods; the transactions costs associated with producing either good declines with the degree of complementarity (Klein, 1987).

People in the United States during the late nineteenth and early twentieth centuries faced clear financial incentives to eliminate mosquitos, a carrier of diseases like yellow fever and malaria. This is particularly because they tied the collective good of mosquito abatement with private goods like homeownership, property values, club property, prestige, and well-being. Howard (1902: 168) states that,

> …a mere passing thought shows the economic loss to a neighborhood in the prevalence of malaria. While the death-rate may not be high, the number of persons incapacitated for their full share of work is always great. Families suffer in one way or another, and the community, when the matter is considered in a broad way, is a great loser. Aside too, from malaria, it is perfectly obvious that a mosquito-ridden neighborhood is not a desirable place of residence. The very fact of the abundance of mosquitoes keeps real estate values at a depressed point.

Frederick Beech, an editor of the Scientific American, reported to Howard an example from Stratford, Connecticut in the 1890s (Howard, 1910: 42). This report shows how entrepreneurs eliminated local mosquito populations:

> In the town of Stratford, Conn., where I have resided for the past forty-five years, we have been greatly plagued by swarms of mosquitos, so great in fact, that the "Stratford mosquito" became a well-known characteristic of Stratford. We have in the southern part of our town, bordering on the sound, several acres of marsh-land or meadow, which would become periodically overflowed with water in the summer and a tremendous breeding ground for mosquitos, and this plague to the town continued until about 1890-91, when a party from Bridgeport, Conn., purchased a large section of the meadows and began to protect them by a dike, both on the north and south ends, which shut out the water. In addition to this, numerous drain ditches were made which helped to carry the water away. The result of this work made the land perfectly dry and spongy, so that after a rain no pools collected on the surface of the meadow and the creation of the mosquitos was prevented. The transformation was so remarkable that people outside the town would hardly believe that it had been effected, and a year or two later the town voted a special appropriation of $2,000 to the party who undertook to build the dike and render the meadows mosquito-proof. It had also the effect of placing on the market a large tract of land elevated from the sound, for residences, and as many as twenty-five summer residences have been built upon this land bordering on the sound, and the number is increasing each year. They are free from mosquitos, so that the operation shows the economy and the benefit that will result by using some means for eliminating the mosquito-breeding pools." (Howard, 1902: 208-209).

This report shows how "the party from Bridgeport", in their search for profit, innovated

by tying mosquito elimination with the purchase of summer homes.[8] Entrepreneurs also eliminated mosquitos and drained bodies of water due to the value of land for agricultural use. This was especially the case in New Jersey for the production of cranberries, asparagus, and onions (Shaler, 1902: 71-74; Howard, 1910: 10). Shaler (1902: 73) estimates that one acre of cranberries yields $100 per year.

Even when organizations do not face a clear profit motive, they may still face incentives to organize prevention campaigns. Howard (1901: 208) describes the success of a country club in New Jersey:

> In the work which was done by the Richmond County Club of Dongan Hills, New Jersey, under the leadership of Mr. W. C. Kerr…considerable drainage of fresh-water swamps above the seacoast bluffs was carried on with great success and at a minimum of expense. This work, together with the use of kerosene upon larger pools, resulted in complete relief from the attacks of the fresh water mosquitos, which during the early summer had always been numerous and ferocious…

This country club even attempted to purchase adjacent land in order to control the mosquito population, but the owners refused to sell. In this case, mosquito prevention complemented the prestige of the club, lowered the annoyance of mosquitos, and solidified its attraction to prospective and existing members. Howard (1901: 211) also writes that "a company of wealthy men who have summer homes on the north shore of Long Island, in the vicinity of Oyster Bay, Cold Spring Harbor, Lloyd's Neck, and Center Island, [plan] to spend several thousand dollars in this kind of work during the summer of 1901, with the sole view of reducing the summer mosquitos of that region." This group of wealthy individuals later supported the North Shore Improvement Association, which

[8] Howard (1902:172) suggests that the publication of his experiment on kerosene facilitated mosquito control across the country. The report, published in the fifth volume of *Insect Life* (1892), demonstrates the effectiveness of kerosene as an insecticide and generated requests for additional information and articles, as well as further experiments.

helped to survey the magnitude of the mosquito problem in northern New Jersey and financed drainage projects to eliminate mosquitos (Shaler, 1902; Howard, 1910: 9-10).[9]

Other examples of tying come from various universities in the United States during the late nineteenth century. Princeton University competed with other schools by claiming that its relatively high elevation provided a healthier environment for students (Deaton, 2013: 98). For a more active approach to mosquito abatement, Mr. H. E. Weed treated with kerosene eleven large water tanks around the campus of the Mississippi Agricultural College (Howard, 1902: 172), which is Mississippi State University today in Starkville, MS. Similarly, Professor V. L. Kellogg of Stanford University experimented with kerosene and filing post-holes, which eliminated local mosquito populations (*ibid*). That mosquito elimination services were provided in multiple academic environments suggests academic administrators face incentives to care for the health and well-being of their students, an input into the wealth and prestige of a school.

Prevention campaigns within private sector firms represent another entrepreneurial form of disease prevention. While firms are engaged in the production and exchange of various goods and services, they may find it profitable to prevent an infectious disease from spreading. Firms like the cotton mills of Roanoke Rapids, North Carolina, the St. Louis Southwestern Railway and the San Augustin County Lumber Company in eastern Texas, and the Tennessee Coal, Iron, and Railroad in Alabama faced financial incentives to prevent malaria because it increased the productivity of their

[9] On additional associations that helped to finance mosquito abatement services across New Jersey, see Headlee (1921). On the New Jersey Mosquito Extermination Association, see Proceedings of the Annual Meeting of the New Jersey Mosquito Extermination Association (1914).

workers (Ezdorf, 1916; Hovenberg, 1918 and 1919; Steel and Iron, 1915). The firms in Roanoke Rapids and in eastern Texas helped to mitigate CA problems by monitoring workers in a gang-labor system, through centralized housing, and best-yard competitions (Carson, 2016). An association of mining companies in Sardinia also helped to prevent the burden of malaria in the early twentieth century (Snowden, 2006).

Mining companies throughout sub-Saharan Africa have also prevented malaria. From 1920 to 1950, copper mining firms in northern Rhodesia (present day Zambia) like Roan Antelope Copper – led in part by Alfred Chester Beatty – realized the burden of malaria, analyzed the geographic and ecological environment, and implemented mosquito-elimination campaigns (Watson, 1950; Uitzinger et al., 2001). AngloGold Ashanti, a gold mining company with operations in Ghana, Guinea, Mali, and Tanzania, implemented an indoor residual spraying and larvicide campaign in the mining city of Obuasi, Ghana (Ebama and Urbach, 2011). Their campaign reduced the prevalence of malaria by 80% between 2005 and 2008. In South Africa and Mozambique, Illovo Sugar Limited employs over 30,000 workers and is one of the world's largest sugar producers. Malaria was burdensome as many of the company's workers were seasonal and were employed in the hotter, more humid months. In 2006, the company implemented a malaria elimination campaign by using rapid diagnostic tests, bed nets, and larvicide, which resulted in an overall decline of 7,800 cases of malaria amongst employees, particularly in Mozambique (*ibid;* also see Bate, 2000).

During the 2014-2015 Ebola epidemic, eleven of the largest concession firms in Liberia helped successfully to prevent the spread of Ebola amongst workers, their

dependents, and the local communities (Carson, 2017a). Most of the firms reported zero cases of infection, despite large workforces and larger communities. The Firestone Natural Rubber Company, a concession suffering the largest outbreak and a particularly hard-hit area, reported 72 cases of infection.[10] Their efforts helped to prevent Ebola amongst its workforce of around twenty thousand, as well as the larger community of 60,000 to 80,000 people, by implementing screening rules and repurposing the firm's organizational structure (Reaves et al., 2014). Similar responses in Liberia include the Sime Darby Plantation, a concession that produces palm oil, and ArcelorMittal Liberia, a steel concession.

IV Liability Law as a Means of Disease Prevention

Liability law is another institution that can influence preventative behavior and the CA problem. The application of liability law requires that people who cause a negative externality are 1) determined to be proximately at fault and 2) compensate those who are harmed. If this kind of law is clearly written and enforced, it will raise the cost of engaging in activities that cause harm (Buchanan and Stubblebine, 1962; Buchanan, 1973; Epstein, 1979).[11] As a way to internalize externalities, especially instead of collectivization, Buchanan and Faith (1981: 101) suggest: "To the extent that the entrepreneurs anticipate such effects, and are liable for possible damages…they can

[10] In conjunction with the International Health Division of the Rockefeller Foundation, Firestone also experimented with plasmoquine as a way to interrupt the transmission of malaria in the early 1930s, which helped to lower prevalence rates (Barber, Rice, and Brown, 1931).
[11] Particular legal regimes also influence preventative behaviors, i.e., strict, comparative, and contributory liability. I thank William Shughart for making this distinction.

proceed without generating net 'social damage,' measured in some *ex post* sense. They suffer the consequences of their action." In this way, liability law encourages individuals who might cause harm to anticipate the full cost of harm, and bear those costs.

Related to activities that spread infectious diseases, a liability law can raise the cost of behaviors or activities leading to a higher prevalence rate of disease. The implementation of this means of prevention requires that people know how a disease is spread, as well as symptoms that provide clear indicators of harm. A liability law of disease also requires a clear indicator that the disease is spread by the particular actions of particular people. Thus, the biomedical and epidemiological characteristics of infectious diseases suggest that liability law may be appropriate for some diseases, but not others. Malaria might be a candidate for a liability law, given the disease is easily identifiable and its modes of transmission are known. Ebola may be easily identified, but it may be difficult to identify which person or persons caused the infection. As death is more likely with Ebola and individuals may not be able to claim damages, the expected benefit of a liability law is lower. Similarly, the symptoms of HIV may be difficult to observe, at least prior to the acquisition of AIDS; it may also be difficult to establish how a person became infected.

The legal institutions of twentieth century America helped to align the private interests of entrepreneurs with the social goal of malaria prevention. The threat of punishment and fines, established when someone's actions clearly increase the prevalence of a disease, raise the cost of infectious behavior. Price (2010) surveys how

southern states in particular relied on legal institutions to punish infectious behavior.[12] Most interestingly, Price notes that the process of litigation helped to inform the public about how malaria spreads, which knowledge may have been delayed otherwise, especially in rural communities of the early twentieth century.

In order to harness the power of running water in the early twentieth century, hydroelectric power companies constructed dams that created hundreds of miles of shorelines, which proved to be hospitable to local mosquito populations. People in the local communities quickly associated these construction projects with rising malaria rates and, in consequence, initiated legal proceedings. The construction of hydroelectric dams usually was associated with an "epidemic" of damage suits in North Carolina, South Carolina, and Alabama (Griffitts, 1926: 368). According to Doran (1968), a circuit court in Marion County, Tennessee, ordered the Chattanooga and Tennessee River Power Company to pay a local resident $3,000 because he had been infected with malaria.

To lower the expected costs associated with going to court and compensating victims, hydroelectric power companies discovered that it was cheaper to eliminate malaria on their own. For example, between 1920 and 1926, residents along Spring Creek in Georgia fought a power company that owned and operated the dam across the river, which increased the prevalence of malaria around the resulting pond (see the comments of Dr. M. A. Fort, in Smillie, 1927). During that time, ownership of the company changed hands multiple times and, in the summer of 1926, citizens living near the pond filed a

[12] Price (2010) references the following cases as some of the earliest legal proceedings dealing with liability and malaria: Godwin v. Atlantic Coast Line Railroad Co., 120 Ga. 747, 48 S.E. 139 (1904); Chesapeake & Ohio Railway Co. V. Whitlow, 51 S. E. 182 (Va. 1905); Towaliga Falls Power Co. v. Sims, 6 Ga. App. 749, 65 S.E. 844 (1909).

lawsuit against the owners. As a result, the owners hired experts on mosquito control and sprayed all parts of the lake with insecticide, which they expected to lower the prevalence of malaria. In correspondence with W. G. Smillie (1927), W. G. Stromquist, an engineer with the US Public Health Service, suggests that water companies throughout the Atlantic and Gulf states had implemented malaria control campaigns on a larger financial scale than all other anti-malaria activities in the country, and that they did more to increase annual incomes for the Atlantic and Gulf States than any other business development.[13]

A final example comes from the Duke Power Company. In correspondence with Clark (1931: 447), Dr. Boldridge, a company physician, states that,

> Eight years ago I filed some records which I believed I would never need. Our general attorney called at my office last spring and asked me about certain people living in this area who were talking about bringing suit for malaria against the company. I looked back in my records. In this family of seven five gave a history of malaria two years before the impounding project. I had not only the personal history, but had a record from the family physician. All I had to do was to give this to the lawyer and when he told their attorney they had had malaria previously he knew it was useless to bring suit.

This passage demonstrates the incentive liability laws establish to conduct malaria surveys, an important part of anti-malaria campaigns. The benefit of taking surveys and recording the magnitude of the malaria problem – in terms of future legal cases prevented – outweighed the present costs of conducting survey work. In this case, keeping such records saved the Duke Power Company the time and resources of debating whether or not its projects had caused malaria. Boldridge suggests most hydroelectric power companies faced similar incentives. He even suggests that firms mitigated another source of liability by hiring only healthy laborers.

[13] L. T. Coggleshall, a malariologist with the Associated Gas and Electric Company, noted in November 1929 that the owners of public utilities had recently taken over the control of malaria (Coggleshall, 1930).

V Informal Norms as a Means of Disease Prevention

Informal norms are institutions that resolve the CA problem of disease prevention by altering the costs and benefits people face regarding preventative behavior (Carson, 2017b).[14] Like all norms, informal norms specify how people should behave in relatively predefined circumstances. Following Brennan et al. (2013), there are three features that distinguish informal from formal norms. First, informal norms are primary rules that influence behavior with few secondary rules specifying when the primary rule is to be followed or by whom, let alone how the rule is to be enforced. The second distinguishing feature is that informal norms rely on decentralized enforcement; enforcing an informal norm must be the responsibility of everyone in a group and usually involves social sanctions (Brennan and Petit, 2004).[15] The final distinguishing feature is that a normative principle established by an informal norm corresponds to a set of normative attitudes. Brennan et al. (2013: 46) shows that informal norms are constituted by *de dicto* normative attitudes, which are generated from the beliefs and values most people regarding a primary rule.

Informal norms can encourage potentially preventative behavior regarding the spread of HIV, namely safe sexual behaviors.[16] As people learned to associate HIV with risky sexual behaviors like unprotected anal intercourse (UAI) in the 1980s, a set of informal norms encouraged the use of condoms as a specific kind of preventative

[14] This section relies on Carson (2017b) for arguments related to the role informal norms play in resolving the CA problem of HIV prevention.
[15] On the importance of enforcement for cultural codes, from the treatment of POWS to the regulation of illicit behavior amongst pirates, see Leeson (2012).
[16] Between 1981 and 1992, newly diagnosed AIDS patients, older than 13 grew from 318 to 75,457; between 1981 and 1995, AIDS related deaths grew from 451 to 50,628 (Torian et al., 2011).

behavior. For example, the use of condoms increased from less than 1 percent in 1981 to 19 percent in 1985, to 60 percent in 1986, and to 71 percent in 1987 (Turner et al., 1989: 133). This dramatic change surely is the result of the large expected costs of acquiring AIDS (Posner and Philipson, 1993; Ahituv et al., 1996), but also from a set of informal norms known as the condom code (Chambers, 1994).[17] The primary rule, stipulated by the code, is that people use condoms whenever they engage in anal intercourse. The code suggests that, "Not wearing a condom is not simply unwise; it is wrong. Not wearing a condom violates obligations to other gay men and, in the views of some, obligations to a larger gay community…" (Chambers, 1994: 353).

The code was widespread throughout gay communities, which raised the cost of unprotected, risky sexual activity. Health and activist organizations throughout gay communities bolstered the code through their communications with the general public: "Every advertisement, poster or pamphlet advising men to use a condom carries [an important message] … using a condom is the right thing to do. Even messages that seem primarily informational are read by men who already know how HIV is transmitted, already know that condoms can reduce the likelihood of transmission and, in most cases, believe that others expect them to use a condom. In this sense, these messages remind us of an obligation" (Chambers, 1994: 360). These informational posters and advertisements helped to create common knowledge that everyone demands the use of condoms, everyone knows that everyone demands the use of condoms, and so on.

[17] Other informal norms may have also influenced sexual behaviors and HIV prevalence. On norms regarding serodisclosure, see Parsons et al. (2005) and Duru et al. (2006).

As the condom code is a set of informal norms, there are few secondary rules to specify when and where the rule applies or is to be enforced. For example, it is not clear which partner should provide condoms, whether a particular partner should require the use of condoms, the magnitude or kind of punishment regarding the failure to use condoms, etc. One set of related norms has emerged related to disclosing one's HIV status. That is, "The person who assiduously uses condoms has no obligation under the rule to be tested for antibodies to the Human Immunodeficiency Virus (HIV) or to inform his prospective sexual partners of his HIV status, even when he knows himself to be infected" (Chambers, 1994: 353). This is a murky issue depending on particular normative attitudes, but the condom code facilitates sexual interactions, as well as HIV prevention, by suggesting people always use condoms.

While the condom code stipulates a primary rule and involves some secondary rules, the effectiveness of the code depends critically on its enforcement. This is evidenced by the fact that not everyone followed the rule. Reasons for the lack of condoms vary from ignorance, forgetfulness, and risk-seeking behavior; using condoms can inflict various costs, from a feeling of embarrassment when purchasing condoms, to the displeasure of sex with a condom, to being hard to find (Turner et al., 1989: 288). Regarding the code, "Many men know the rule but ignore it, while many others accept the rule and intend to use condoms whenever they have intercourse but often fail to do so" (Chambers, 1994: 359). In communities of black men who have sex with men (MSM) in Atlanta and Chicago, Kraft et al. (2000: 436) state that, "Although MSM groups may implicitly condone unsafe behavior, with few exceptions, the men who talked about

norms said they were encouraged to 'stay safe.' Houses, gay families, and gay friends encourage men to stay safe, either verbally or by providing condoms." That the primary rule is not perfect does not suggest it is not an important influence on behavior; while important for HIV prevention, the primary rule regarding the use of condoms may be countered by other goals people have, as well as by other rules they follow. When men failed to follow the primary rule, it is not necessarily because the rule played a trivial role in their sexual behaviors.

As the condom code is informal in nature, decentralized monitoring and enforcement is required.[18] Internal and external sanctions emerged that encouraged the condom code throughout gay communities. Expressions of guilt, regret, and shame are reported when people fail to use condoms: "Unprotected sex … has shifted in the eyes of large numbers of gay men from being merely imprudent to being wrong" (Chambers, 1994: 369-370). As members of gay communities internalized the condom code, it became costly to break the rule and their sexual behaviors changed accordingly. Chambers (1994: 361) also discusses the possibility of external or social sanctions, whereby people are shunned, ostracized, or stigmatized for failing to use condoms. One respondent in a small study of sexual practices among MSM recalls how the use of condoms was monitored at parties and people were kicked out for not using them

[18] While formal rules regarding sexual activity and HIV were implemented in the United States, their efficacy has not been established (Lazzarini et al., 2002). This is especially since people already believe it is wrong to purposefully and knowingly infect others (Burris et al., 2007; McCallum, 2014). People may not know of the relevant law or statute criminalizing potentially infectious behavior (Gostin and Hodge, 1998; Schwarcz et al., 2004; Hopkins et al., 2005). Furthermore, formal rules can be vague, they may not address relevant behaviors leading to HIV infection, and they may vary across jurisdictions (Galletly and Pinkerton, 2004; Frederick and Perrone, 2014).

(Carballo-Dieguez, 2001: 228). Furthermore, people may be considered to lack pride in the community if they fail to follow the condom code (Chambers, 1994: 341).

The final feature of the condom code is that its rules are derived from widely accepted normative attitudes in gay communities regarding the goals of prevention. While people still engaged in risky sexual behaviors, they believed in the normative attitudes supportive of the norm. Chambers says that, "Only rarely do men assert that they have intercourse without a condom because it is their right or desire to do so. They offer either rationalizations ('I believed that my partner's HIV status was the same as mine') or confessions ('I was drunk and I didn't have a condom'). Nearly all accept the premise that protected sex is the norm" (Chambers, 1994: 364). Additionally, "Consider first an ad prepared by the American Foundation for AIDS Research (AmFar) that has been widely published in media reaching gay men. Its central image is a king-sized condom. Above the condom is a headline – "What the Smart Set is Wearing this Winter" – that appeals to both self-interest and self-esteem. Below the condom is a direct plea for altruism: 'Help stop the spread of AIDS.' Using a condom is important for saving the lives of *others*" (Chambers, 1994: 361). Statements like these indicate the condom code was constituted by the *de dicto* normative attitudes found throughout gay communities.

VI Conclusion

Disease prevention can be achieved in theory and in practice without resorting to an omniscient and benevolent public health planner. The task economists can and should focus on, thus, is the diverse ways in which people perceive the costs and benefits of

prevention, the multiple margins of responsiveness, and how various institutions influence that responsiveness. The institutions of disease prevention have implications for the practice of public health, as well as for economic development.

That entrepreneurs have financial incentives to prevent infectious diseases, at least at local and regional levels, suggests an underdeveloped pathway to align private and social interests. The entrepreneurial institutions of disease prevention are limited by the extent to which people foresee profit opportunities. Similar to other entrepreneurial endeavors, the profit opportunities related to disease prevention are a function of the multitude of preventative goods and services and the political and social institutions that influence economic activity.

Legal institutions have long been a foundational tool of public health, and they may provide additional insight in explaining differences in prevalence rates across different jurisdictions. For example, a comparative analysis should examine whether areas with strict liability laws, relative to other liability laws, exert a greater influence on preventative behavior. Similarly, the quality of legal institutions or how well a particular liability law is enforced may explain differences in preventative behavior. Of importance, legal institutions are often an arm of government, but there is typically less room for discretion as there is in political and bureaucratic means of prevention. This suggests that the effect liability laws have on preventative behavior, relative to other private and public prevention campaigns, is another comparative exercise that should be examined.

Informal norms influence a variety of behaviors in everyday life, and they have long influenced health behaviors and in particular the spread of infectious diseases (McNeil, 1976; Ranger and Slack, 1996). These institutions are difficult to measure and may be unknown to public health planners, let alone economists, but they may exert a primary influence on human behavior. Indeed, when formal institutions are not capable of resolving collective action problems, as in the case of sexual behaviors, informal norms may have a greater influence. This suggests a better understanding of prevention campaigns should incorporate relevant informal norms.

Incorporating institutional analysis in the economic approach to epidemiology can lead scholars, public health experts, and even people burdened with infectious diseases to a more diverse set of arrangements through which disease prevention can be accomplished. Alternative institutions may not completely resolve collective action problems associated with infectious diseases, but they are more important than previously considered in most economic studies of disease prevention. This is especially the case given dysfunctional governments of varying shapes and sizes and the ability of private actors to seek solutions for their problems. It is no longer appropriate to assume private individuals fail to internalize the benefits of prevention, unless relevant entrepreneurial, legal, and cultural institutions are accounted for.

CHAPTER TWO

I Introduction

Why did cotton mills in Roanoke Rapids, North Carolina and a railroad in eastern Texas prevent malaria between 1910 and 1920? As local and federal anti-malarial services were either lacking or inadequate, these firms realized malaria imposed significant financial and physic costs on their workers and local communities and implemented their own anti-malarial programs. Motivated by increases in labor productivity and profit, the firms transformed their normal production processes in order to organize the necessary labor and resources to eliminate mosquitos, drain bodies of water, and ultimately disrupt malaria's transmission cycle. In this way, the firms alleviated the commons-like problems associated with malaria prevention, issues of externalities and free-riding.

These efforts deserve analysis for a number of reasons. First, standard economic theory focuses scholarly attention away from firm-led prevention because of positive externalities and the resulting free-rider problem. Tullock (1969), in reference to a community-wide mosquito spray, argues that it is not rational for individuals, or firms for that matter, to voluntarily contribute to a collective good, like malaria prevention, when

free riding is possible.[19] Furthermore, Allen and Croxson (2006) and Jamasji-Pavri (2006) suggest contracts are not effective means for governing disease control because contracts are fundamentally incomplete in situations of infectious diseases due to uncertainty, in addition to the externalities associated with prevention. Firm-led malaria prevention is likely to be underexplored given that economists have theoretically grounded reasons to expect malaria prevention to be provided by governments.[20]

Second, the federal government in the United States became a larger and larger force preventing the disease (which eventually was eliminated) in the twentieth century. Federal involvement with malaria prevention began in 1914 through the administration of the Public Health Service (PHS) and operated through WWI, the Great Depression, and during and after WWII. Accordingly, epidemiologists, medical historians, and other public-health scholars usually attribute the decline of malaria to more federal intervention (Humphreys, 1996 and 2001; Sledge, 2012; Sledge and Mohler, 2013; Kitchens, 2013a). State and local governments were another source of malaria prevention, but to a lesser extent. While the Constitution granted legal authority of disease coordination to individual states (Trask, 1911; Dubach, 1916), they were rarely capable of doing so. According to LePrince (1928: 1262),

[19] Standard theories do not suggest it is impossible for uncoordinated individuals to prevent malaria – only that prevention will be less than if the group were coordinated.
[20] There are notable exceptions. Fishback (1992), for example, shows that sanitation services in villages associated with the American bituminous coal industry were comparable, and often better than, public services. Galiani et al (2005) shows that child mortality decreased as the result of water privatization in Argentina. Troesken (2015) shows that in the 18th and 19th century United States, private companies were encouraged to provide public water supplies, which lowered typhoid rates, but only through government grants of monopoly power.

> previous to 1914 probably less than six communities had undertaken malaria-control measures, and the results of such limited effort were unsatisfactory. Up to that time, not a single State health department was taking any action toward malaria elimination, although in many counties malaria was the most important health problem. No State or county had made any appropriation for malaria reduction.

Thus, any economic or medical history dealing with malaria in the United States is likely to focus on the role played by the federal government.[21]

This paper does not deny the historical trend of increasing government involvement; rather, it shifts focus to alternative means of prevention, private malaria prevention through the firm, and develops an economic theory explaining this behavior. As such, it draws from and complements the large literature on the private provision of public goods.[22] Prior to the development of extensive federal and state malaria prevention, private malaria prevention was a significant alternative to mitigate the burden of malaria. Without recourse to governmental public health services, private individuals sought, found, and relied upon private malaria prevention.[23] In two case studies below,

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[21] The difficulty of obtaining accurate historical records on firms is another reason why it is difficult to satisfactorily observe firm-led prevention. This creates a bias that attributes the decline in malaria to public services; it is difficult to correlate malaria prevalence with firms that may have provided malaria prevention, but, alas, cannot be observed.

[22] See Demsetz (1970), Brubaker (1975), and Cornes and Sandler (1996) for theoretical expositions on public goods and, in particular, their private or voluntary provision. For arguments on specific cases, see Coase (1974), Cheung (1973), Klein (1990), Anderson and Hill (2004), and Bogart (2005). Foldvary (1994) and Beito et al (2009) provide historical evidence on private communities and the private provision of public goods in cities. Smith (1980) and Harrison and Hirshleifer (1989) detail how uncoordinated groups can provide public goods in experimental settings.

[23] Cases of firm led malaria prevention are numerous. In addition to the cases below, there is evidence to suggest the Tennessee Coal, Iron, and Railroad and the Norfolk and Western Railroad provided anti-malarial campaigns in Alabama and Virginia, respectively (Steel and Iron, 1915; and Annual Report,

firms asserted control over disease prevention and mitigated the burden of malaria for their employees and local communities. Ownership over these programs were valuable because malaria prevention was directly related to productivity. Furthermore, the firms' hierarchical structure lowered the cost of monitoring and organization.

Furthermore, the firms did not prevent malaria during the rest of the twentieth century because ownership over malaria prevention became less valuable. The benefit of firm-led malaria prevention declined with a declining overall rate of malaria, an increasing role of the federal government, and technological innovations that limited exposure to mosquitos.

Developing a better appreciation for firm-led malaria prevention is important for a number of reasons. First of all, this kind of malaria prevention suggests that, for many people in parts of the developing world where malaria is still a significant burden and where anti-malarial public health services are weak – as they were in the United States during the early twentieth century – firms can help to lower the burden of malaria. Second, economists should find this of interest because it complements standard theory by showing some of the conditions under which firms provide goods typically considered to be public goods. That is, the firm is one organization with the interest and capability to resolve complex problems associated with infectious diseases.

1916). Ezdorf (1916) also discusses the case of Electric Mills in Mississippi. The comments following Hovenberg (1918) also suggest that the Missouri Pacific and Illinois Central railroads provided malaria prevention. So did an association of coal mining companies in Sardinia during the early twentieth century (Snowden, 2006), as well as mining companies in Ghana and South Africa during the later half of the twentieth century (Ebama and Urbach, 2011). There is also a literature on workplace programs devoted to preventing HIV/AIDS and TB in southern Africa (Yassi et al, 2013). I focus on two cases in particular merely because I am more familiar with them and historical evidence is more available.

The paper proceeds as follows. Section II explains the theory of firm-led disease prevention. Section III describes two cases where firms led successful anti-malaria campaigns. Section IV discusses the main factors that facilitated malaria prevention in the cases. Section V shows why private efforts were less valuable during the mid-twentieth century. Section VI concludes.

II Property Rights, Disease Prevention, and the Firm

In addition to problems of uncertainty and information asymmetry, one of the fundamental problems associated with infectious diseases is that property rights over prevention and control are held in common (Roberts, 2006: 10). People facing such an initial allocation of rights have little incentive to provide disease prevention; as a result, people face a higher probability of infection than if property rights were clearly defined and enforced. As Demsetz (1967) and Barzel (1997) show, the initial assignment of property rights can change, particularly when the costs and benefits of having private property rights change.[24] Thus, disease prevention can be aided by a reassignment of property rights, the substitution of common property towards private property, which gives the parties involved incentives to provide prevent disease.

Following Demsetz's logic regarding the formation of property rights, the owners and managers of firms will form property rights over disease prevention and control when the benefits of prevention outweigh the costs of prevention. Allen and Croxson (2006) and Jamasji-Pavri (2006) focus on the costs of uncertainty, the external effects of

[24] Demsetz depicts the change in property rights over hunting grounds, from common to more private, as the value of beaver fur increased in the Labrador Peninsula during the 17th and 18th centuries.

prevention, and the difficulty of assigning property rights, which may deter firms from prevention and control. Yet, the benefit of prevention could outweigh these costs, which will lead them to provide disease prevention. Below I describe the benefits and costs firms may face regarding disease prevention and control.

Firms can invest in their workers by providing disease prevention and control; the return is directly related to the size of their workforce. The more a disease burdens a population, the more a firm has the opportunity to improve labor productivity. Firms face similar incentives if the public good of disease prevention can be tied to a private good (Klein, 1987). For example, clearing a swamp from infectious mosquitos influences the value of houses in the swamp's vicinity. To the extent firms own physical and human capital whose value is determined by malaria prevention, the firm can exclude others from free-riding by offering these relatively private goods.

Firm-led prevention is also likely to take place when a firm faces an inframarginal externality (Buchanan and Stubblebine, 1962). Private benefits are obtained from a good regardless of whether or not other firms or other parties are affected. For example, a firm may screen the buildings where its workers work or it may clear swampland. While these activities benefit the local population by decreasing the probability of infection, it primarily benefits the firm in the form of higher productivity and/or higher profits.

Complementary goods are another way to internalize the benefit of production (Cheung, 1973; and Cornes and Sandler, 1996). When complementary goods are produced together firms can often internalize the positive externality of one good by

producing another good, as Cheung showed with bees and apple orchards.[25] Producers thereby have an incentive to produce more than would be the case otherwise. Two firms can engage in joint production whereby one produces disease prevention and the other compensates.

Firms may face a variety of costs regarding disease prevention. There are production costs of actually preventing the spread of disease, and there are transaction costs dealing with organizing the campaign and monitoring the behavior of subordinates. The kind of disease may preclude available means of prevention techniques. For example, while Malaria can be prevented by draining swampland, among other measures, Ebola requires limiting physical contact with potentially infected people. Furthermore, both of these diseases are easily prevented when compared to a disease like measles, which spreads quickly through human populations.

Organization and monitoring costs arise because disease prevention and control requires inputs from multiple people, each of whom are self-interested, who own different resources. Known simply as a principal-agent problem, the problem here is that when one person desires malaria prevention and hires others to perform, the workers have an opportunity to shirk because it may be difficult to monitor their behavior. There are a variety of situations where monitoring costs are particularly burdensome. For example, when a group of people are tasked with clearing a large plot of land, which has varying terrain – from flat, grassy parts, to swampy areas – it may be costly to learn which people actually did their jobs. In this example, not only is there the cost of monitoring a large

[25] Cheung also focuses on the particular contractual arrangements between bee farmers and orchard owners, which helped to lower the cost of exclusion.

tract of land, but it may be difficult to compare the work of laborers clearing weeds and underbrush with those working in the swamp. This problem is exacerbated when there is considerable time between the preventative activity and its expected outcome. For example, if a group of workers is hired to clear a parcel of land in the fall, to prevent malaria in the following spring, it is more difficult to attribute particular inputs with the actual outcome.

Thus, the residual claimant of prevention and control, the owner of a firm, must allocate a share of total resources towards monitoring the performance of others in order to successfully prevent infectious diseases. Through a variety of incentive schemes, the owner of a firm can develop a comparative advantage in monitoring (Barzel, 1997). First, the owner can devise a contract in order to specify particular outcomes; failure to achieve those results have certain consequences. Of course, not every eventuality will be accounted for, but no contract is perfect. Within profit seeking firms, owners face incentives to learn and devise better contracts, which mitigate such concerns over uncertainty. Second, the owner of a firm can rely on a hierarchy which tasks subordinates with monitoring each other instead of being monitored by a single owner or manger. Creating a hierarchy gives subordinates or managers the status of residual claimant. This manager can then devise further schemes to incentivize workers (Miller, 1993). Finally, the owner of a firm can create a prize or contest within a department or across the firm to encourage productive behaviors. In the hope of winning, workers will engage in more productive behavior (Lazear and Rosen, 1981).

III Firm-led Malaria Prevention

The following two cases from the United States show why and how firms prevented malaria between 1910 and 1920. These cases are the more prominent examples of firm-led malaria prevention (see, for example, the other cases mentioned in fn. 5).

3.1 The Mills of Roanoke Rapids, North Carolina

Roanoke Rapids, North Carolina developed as an industrial center along the Roanoke River in the late nineteenth century. The town began to develop when the Roanoke Mills Company began production around 1897. The town grew to a population of about 700 by 1900. By 1912, the larger town covered about four square miles, and three firms employed most of the local workforce. These firms were the Rosemary Manufacturing Company (ROMAN), the Roanoke Mills Company (RMC), and the Patterson Mills Company (PMC), which employed about 1,850 people by 1912 (Hoyle, 1971). These firms, while separate entities, were heavily connected by Samuel Patterson, who helped build each of them into the major firms of the town (Denny, 1972; Allen and Travis, 1920).[26] The firms were associated with the smaller towns of Rosemary mill village, Roanoke Rapids, and Patterson mill village, respectively.[27] By 1913, approximately 2,000 people lived around the Rosemary plant, 1,800 around the Roanoke Rapids mill, and 300 around Patterson mill.

[26] According to Denny (1972), Patterson served as general manager and treasurer of the RMC between 1896 until 1926. Patterson was treasurer of ROMAN since its founding in 1900 until 1919, when he became president and manager. Samuel Patterson was one of the founders of PMC around 1910, and served as its general manager.

[27] Unless otherwise noted, I define Roanoke Rapids as the entire town that encompasses the four blocks of Roanoke Rapids, Rosemary village, and Patterson village.

The ecological and geographical conditions of Roanoke Rapids were particularly ideal for breeding mosquitos, which spread malaria. In 1913, Henry Carter, a senior surgeon with the United States Public Health Service (USPHS), surveyed the small town of Roanoke Rapids and Patterson village and found mosquito larvae in almost every part of every stream and pool examined. Carter spent about four days in Roanoke Rapids to discuss sanitation and antimalarial work with the mayor, the various owners of the mills, and health officials. He concluded that mosquito populations flourished in the town because of its less porous soil, abundant rivulets and pools of standing water, and the lack of natural predators like minnows (Carter, 1913). R. H. von Ezdorf, a surgeon with the USPHS, also surveyed Roanoke Rapids in 1913 and found that the main waterway branched out to the mills and through the town, which passed under streets and buildings and emptied into a canal; the waterways created large, flat marshy areas (Ezdorf, 1916).[28]

These conditions, of course, left Roanoke Rapids burdened with malaria. Ezdorf (1916) specifies that most of Roanoke Rapids was burdened by malaria, while Rosemary village faced less of a burden. Ezdorf explains the difference by noting that houses in Roanoke Rapids proper and those in Patterson village were closer to mosquito-breeding areas, and well within the flight range of mosquitos.[29] A health officer of the mills reported that approximately 75 percent of the population of Roanoke Rapids had malaria during the summer of 1910 and the incidence of malaria was similar between 1911 and 1913. Furthermore, approximately 50 percent of medical services were related to malaria

[28] The North Carolina Board of Health asked the surgeons to survey malaria rates in 1913. Only those areas with enough interest and income would eventually carry out antimalarial campaigns.
[29] Thus, it seems Ezdorf focuses his attention on the malaria problem associated with Roanoke Rapids, proper, and Patterson. Similarly, for the anti-malarial work of those places.

during the summer of 1913. In October of 1913, a census was conducted to learn about people's history with chills and fever, which are common symptoms of malaria. The census was conducted in the four blocks of Roanoke Rapids proper. Of all persons who lived there, about 500 people, approximately 233 reported having those symptoms after June 1, 1913 (Ezdorf, 1916).

From the recommendations of the USPHS surgeons, the mills, along with other companies of the area, agreed to finance an anti-malarial campaign (*Roanoke Rapids Herald*, April 9, page 1, and March 5, page 1-2, 1915).[30] The owners, managers, and health officials realized this work would improve the health of their workers and the local population, which would also increase labor productivity. Samuel Patterson, a leading businessman and founder and treasurer of the Roanoke Mills Company (see fn. 9), was particularly concerned with the health of his workers (Allen and Travis, 1920). According to Ezdorf (1916: 618),

The directors of the mills indicated their desire to undertake what was necessary to control the malaria, to give their financial support, and to secure the cooperation of the other mills interested. The health officer at once took steps to secure a fund for conducting an antimalarial campaign, making plans for the work to begin early in the year. The directors of the various mills gladly contributed to making up the necessary fund for undertaking the project.

The antimalarial campaign began in the January of 1914 and included training streams, straightening banks, clearing underbrush, leveling ditches, cutting new ditches,

[30] These companies included the RMC, the PMC, the ROMAN, the Roanoke Rapids Power Company, and the Beaver Board Company.

and oiling, as well as inspecting and maintaining performance (Ezdorf, 1916).[31] A sanitary inspector monitored the work every week and filled oil cans, from the beginning until November 1. Further evidence regarding how the actual labor force was organized is not available. However, the campaign cost the mills an estimated $3,683.61 in 1914, or $87,904.93 in 2015 dollars. An article in the *Roanoke Rapids Herald* reported that mills and private individuals spent over $3,800 to combat malaria, and that RMC, PMC, and the Roanoke Rapids Power Company contributed $1,000 each to the campaign (April 9, 1915, page 1).

In addition to the willingness of the firms to finance the anti-malaria work, they also placed Dr. Thomas Williams Mason Long in charge of the operations. Dr. Long is well known to be the singular health official responsible for coordinating amongst mill officials, acquiring the necessary funds, and advocating for the anti-malarial work. Around 1910, Samuel Patterson recruited Long as a physician to provide healthcare to workers (Robinson, 1997; Parker, 1943). Hoyle (1971: 189) notes that "using the work of Dr. W. C. Gorgas during the construction of the Panama Canal as his model, Dr. Long, through his personality and persuasion, obtained the cooperation of public officials in a battle for mosquito control. Tedious drainage and oiling of the stagnant waters of swampy low-land areas brought an end to the 'death trap' along the Roanoke River." Dr. Long also encouraged people to take quinine as this was the most effective chemotherapy

[31] During the first year of work, between January 1914 and December 1914, approximately 6.9 miles of ditches were dug; 40 acres of land were cleared of underbrush; 59 wagonloads of tin cans and debris were removed; and 3,000 gallons of oil were used. In Patterson Mill, wastewater was diverted from the bleaching plant to serve as a larvicide.

at the time to prevent infection (*Roanoke Rapids Herald*, Oct. 9, 1914, page 1).[32] Dr. Long even requested an inspection of the anti-malarial work from an engineer with the USPHS (*Roanoke Rapids Herald*, June 26, 1914, page 1). The engineer complimented Dr. Long for the efficiency and intelligence with which the anti-malarial work had been conducted.

The incidence of malaria decreased dramatically between June and October of 1914, which is usually peak malaria season. Dr. Long reports that the average number of cases did not exceed one per day and that "95 per cent of these cases were cases that had given the history of having had malaria during the previous year, and were undoubtedly recurrent attacks" (Ezdorf, 1916: 620-21). Furthermore, an inspection of the ditches and other mosquito-breeding sites found few mosquito larvae. Dr. Ezdorf presents a summary of the results, reprinted in table 1 below.

Table 1 – Results of the Roanoke Mills Antimalarial campaign, Jan. 1914 – Dec. 1914

A comparative statement of the results may be briefly summarized:	
Prevalence of infection shown by blood examinations:	Per cent.
October, 1913	13.75
October, 1914	4.43
Reduction in the incidence of malaria carriers (in 1 year)	67.7
Prevalence of infection shown by house-to-house inquiry	
October 15, 1913	49.8
October 15, 1914 (95 percent of these were relapses)	33.0
Reductions in incidence, clinically reported	33.0

Reprinted from Ezdorf (1916: 621).

[32] In addition to the extensive and coordinated efforts to combat malaria, there is clear evidence to suggest people consumed quinine in Roanoke Rapids. Between June and October of 1913 and 1914, the number of quinine prescriptions declined from 380 to 226, which is indicative of the effect anti-mosquito work had on the prevalence of malaria.

Additional work continued in 1915. Dr. Long secured a fund of $1,500 to maintain existing ditches, dig new ditches, straighten riverbanks, and for oiling sources of water. The mill used approximately eighty-three barrels of oil between April 7 and October 1, 1915; an administrator inspected ditches, oil cans, and the outcomes of oiling were all inspected three times a week (Ezdorf, 1916). In 1916, Dr. Long's work continued with an additional fund of $1,400, financed by the Roanoke Mills Company, the Patterson Mills Company, the Roanoke Rapids Power Company, and the Halifax Paper Corporation (*Roanoke Rapids Herald*, May 18, 1917, page 1).

Early in the twentieth century, blood-smears were the most effective indicator of malaria. Ezdorf reports that in 1913, 55 of 400 blood-smears confirmed the presence of malaria. In 1914, 35 of 780 smears confirmed the presence of malaria. Finally, in September 1915, another blood-smear survey was conducted, which found that 34 cases out of 968 tested positive for malaria. Thus, the incidence of malaria declined from 13.75 percent to 4.48 percent and then to 3.51 percent between 1913 and 1915. From 1913 to 1916, the antimalarial work of Roanoke Rapids decreased the prevalence rate from about one in seven to about one in fifty.[33]

Ezdorf reports that "the manager of the Roanoke Rapids Mills stated that at no time has labor been more efficient and sufficient, attendance more steady, and sickness less, and that the returns for the contribution of $1,000 of this one mill were more than gained in one month's (September) operation of the mill" (1916: 621).We can find

[33] An article in the *Roanoke Rapids Herald* reports on the results of the campaigns between 1915 and 1916 (May 18, 1917, page 1). Blood smears taken by the USPHS show that in 1915, 3.51% were positive cases, and 1.58% were positive cases in 1916.

evidence of the financial benefits of the campaign – fewer days when workers were absent from the mill and increased productivity when they were present – in a letter from S. F. Patterson, treasurer of the Roanoke Mills Company, to Dr. Ezdorf, on December 27, 1915. Patterson states that,

> during September, 1912, we averaged 66 looms standing per day for the want of weavers; during September, 1913, we averaged 25 looms standing per day for the want of weavers; during September, 1914, after the antimalarial work had been completed, we had no difficulty in running our looms, and during September, 1915, we have had the greatest abundance of help.
>
> I told you once before that in September, 1913, we worked 26 days and produced 238,046 pounds of cloth; during September, 1914, we worked 26 days and produced 301,151 pounds of cloth; during September, 1915, we worked 26 days and produced 316,804 pounds of cloth. (Ezdorf, 1916: 624)

Patterson's figures imply that the company increased production by 26.5 percent and 5.19 percent in 1914 and in 1915. Whereas prior to the anti-malaria work, RMC had too few workers, they had to turn workers away as people were no longer burdened by malaria (*Roanoke Rapids Herald*, April 9, 1915, page 1).

As Patterson discusses explicitly, the campaign brought financial benefits to the firm and health benefits to the larger community:

> I will frankly admit that I could not realize what a great change could be brought about by systematic work and with comparatively little expense. The money spent in antimalarial work here has paid the quickest and most enormous

> dividends I have ever seen from any investment, and after having had our experience I would, if necessary, do the work over again if I knew it would cost ten times the amount…
>
> I will close by adding that our experience has taught us that the eradication of mosquitoes is not only the proper thing to do from a strictly health standpoint but it is an exceedingly profitable thing to do (Ezdorf, 1916: 624-625).

3.2 The St. Louis Southwestern Railroad

The St. Louis Southwestern Railroad Company (SSW) covered a distance of over 1,700 miles across, Missouri, Arkansas, Louisiana, and Texas.[34] In 1916 the railroad employed between six and seven thousand workers. The towns of Tyler, Texarkana, Lufkin, and Keltys were some of the main towns located along the railroad, which were particularly burdened by malaria.

Malaria was an annual concern in eastern Texas during the early twentieth century (PHR, 1917). The presence of malaria in this area is believed to be the result of a long growing season, plentiful rainfall, and spring-fed streams, which facilitates mosquito populations during summer months. According to public health reports, about 40,000 cases were reported in 1915, while 12,000 were reported in 1916.[35] For counties of interest to SSW, Tyler county had about 195 cases in 1915 and 82 in 1916; Bowie county, which includes Texarkana, is reported to have had 488 cases in 1915 and 199

[34] A main secondary source comes from Hofsommer (2003 and 2009).
[35] As the report suggests, reported cases are not a true representation of actual number of the malaria count because only 14% of those surveyed responded; the report suggests the estimates underrepresent the actual amount of malaria. Interestingly, this work was initially carried out by Dr. Ezdorf until his death in 1916.

cases in 1916; Angelina County, which includes Lufkin, shows 90 cases in 1915 and 52 cases in 1916.

The burden was further concentrated because most of its workforce came from rural and farming areas in the southern United States, where people were more likely to have malaria. Furthermore, working and living conditions around SSW exposed people to mosquito breeding grounds. These conditions included working near river bottoms or swampy areas; living in unscreened train cars or rooms; and working night shifts. An employee hospital book suggests 2,407 men were treated for malaria between 1913 and 1916.[36] Approximately ninety per cent of these cases were from section workers, extra gang members, bridge builders, and shop employees (SSW, 1921: 19).[37]

After examining hospital records, Edwin Gould, Chairman of the Board of Directors of SSW, realized that malaria imposed significant costs on the company. In the fall of 1916, Gould invested his own money in a trust to be used exclusively for anti-malaria work (Hovenberg, 1918). Dave Morris, a vice president of the company, was made its trustee (SSW, 1921).[38] The expertise and advice of the United States Public Health Service was requested and surveys of SSW areas were completed around January of 1917. These surveys and the income from Gould's trust, facilitated the anti-malarial work, which first began in Tyler and Lufkin, Texas in May of 1917. On July 1, 1917,

[36] The SSW report of 1921 suggests these numbers represent only one fourth of the total number of malaria cases as many workers may have had malaria but did not require hospitalization. Hovenberg (1926) also suggests they may have consulted other physicians.
[37] Between 1913 and 1916, malaria cases accounted for about one fourth to one fifth of medical and surgical hospital cases (SSW, 1921).
[38] Hovenberg states the trust had two purposes. First, it was to increase labor productivity and decrease hospital cases of malaria. Second it was to help local towns and businesses along the SSW lines. By 1920, the "Malaria Prevention Fund" had contributed $41,541.96 for SSW to combat malaria (SSW, 1921: 8).

SSW created the position of sanitary engineer to take charge of the anti-malarial work, and hired Hovenberg, a municipal sanitarian from Dallas, to fill the position; the engineer was a general officer of the company and answered directly to the president (Smiley, 1918; SSW, 1921). By August of 1917 campaigns in Keltys, Farber, and Wildhurst had been carried out, and one had just been started in Texarkana.[39] Similar work continued across east Texas at least until 1920.

In each of the towns, anti-malarial work consisted of destroying mosquito breeding grounds, limiting exposure to infected mosquitos, and by encouraging the consumption of quinine. Field operations were conducted up to three fourths of a mile away from inhabited portions of the communities and included draining, filing, trimming or oiling bodies of water; and filling ponds or streams with top-water fish.[40] By 1920, approximately sixty percent of people in the cities along SSW lines lived in areas with effective malaria control (SSW, 1921).

A variety of mechanisms facilitated effective malaria control.[41] First, a "malaria extra gang", supervised by a competent foreman, was appointed to carry out necessary physical labor, i.e., ditching streams, clearing weeds and debris, and oiling stagnant pools of water. This group of laborers, their supervisor, and inspectors traveled across SSW properties when necessary. Due to the increasing number of areas which came under

[39] A chronology between 1917-1920 of the campaigns can be found in SSW (1921). The report also lists miles of waterways under control, as well as the square miles of control area.
[40] The report of SSW (1921) includes maps of Tyler, Lufkin, Wildhurst, Keltys, Texarkana, and others, regarding water courses that had been placed under control.
[41] Additional anti-malarial programs included the screening of most of the train cars by extra-gang labor, common laborers, and section crews early in the spring of 1917. Furthermore, SSW advocated the use of quinine as a prophylactic and attempted to learn about proper dosages through experimentation. SSW even financed multiple educational programs regarding the epidemiology of mosquitos and malaria; public lectures were given, videos were shown, and essay competitions were held in elementary schools.

SSW's attention, SSW found it more difficult for one sanitary engineer to supervise all of the work; recruiting and training new foremen and inspectors every year for seasonal work also became costly. In the summer of 1919, SSW officials created a Sanitation department to mitigate these monitoring costs (SSW, 1921).[42]

Second, the railroad contracted with a variety of towns and other firms to delineate responsibility and to ensure successful campaigns. In particular, the railroad was only concerned with financing efforts to mitigate mosquito populations that spread malaria (as opposed to a program to kill mosquitos that were a nuisance). Agreements were made with local communities, which included work for field surveys and estimates of the cost, as well as the actual field work (Hovenberg, 1918). For example, in Tyler, where approximately 700 SSW employees lived, the city agreed to pay SSW up to $1,000 for labor, while SSW would provide additional labor and expenses. The cities of Texarkana, Texas and Arkansas, both agreed to pay SSW up to $600; yet, while the cities could not pay in cash, they provided SSW with script to pay for taxes. In Lufkin, SSW agreed to pay five ninths of the cost, while the Lufkin Land and Lumber Company and Mrs. G. A. Kelley paid for the remainder. Finally, in Keltys, the San Augustine County Lumber Company paid for the entire cost of the anti-malaria campaign, while SSW provided the railway with the expertise of its sanitary engineer.

Initially, SSW was the major financier for malaria prevention campaigns in eastern Texas, but the local towns and firms gradually assumed a larger portion of the

[42] The report of SSW (1921) suggests that Gould, the St. Louis Southwestern Railway Corporation, and the United States Railroad Administration helped to finance this department. Furthermore, sanitary inspectors were placed across four divisions of the railroad lines in order to monitor malaria work, all under the Sanitary Engineer. A description of this department's responsibilities is also given. Hovenberg (1926) suggests the department was given the full support of the President and Vice President.

cost (Hovenberg, 1919 and 1926). Of the $4,042 spent of malaria control work in 1917, SSW paid about 53 percent ($2,160); SSW's share declined to 33 percent in 1919, and then to 12 percent ($1,928) in 1920. Local towns increased their contributions to $14,876 by 1920, an increase of approximately 700 percent (SSW, 1921: 40).

Finally, Derivaux (1918), in reference to railroads and malaria prevention, discusses the possibility of creating a competition that will incentivize foremen to maintain the health of their workers; a bonus would be given to the foreman with the healthiest workers. While there is no evidence of whether or not SSW relied on this kind of competition to incentivize malaria prevention, it seems likely. After the sanitation department became a permanent fixture of SSW in 1919, competition was used to encourage cleanliness across railroad stations and even amongst section houses throughout the year (Hovenberg, 1926). Rewards included a trophy cup, and later became paid vacations and cash rewards.

These efforts reduced the incidence of malaria among railroad employees. The title of one of Hovenberg's articles (Hovenberg, 1926) summarizes the overall effect, as well as the magnitude: "How Cotton Belt Cut Malaria Rate 97 Per Cent in Nine Years." Specifically, between 1913 and 1916, an average of 602 employees were treated annually for malaria in the company hospital in Texarkana, but the average fell to 251 malaria patients between 1917 and 1920.[43] If extra gang men are excluded, because they accounted for a significant portion of hospital cases, the three year averages change from

[43] This is a reduction in malaria patients of 58%.

468 cases between 1913 and 1916 to 185 between 1917 and 1920.[44] The same hospital records have been classified according to employee groups. For section workers, extra gang members, and bridge builders, the groups most burdened by malaria between 1913 and 1916, the incidence of malaria is estimated to have fallen by over 86 percent, over 74 percent, and over 89 percent, respectively (SSW, 1921). By 1925, only 22 people among the 9,000-person workforce had malaria (SSW, 1926).

Further evidence suggests that SSW saved approximately $140,300.00 by preventing malaria over four years (SSW, 1921). The report estimates SSW spent about $100 on each case of malaria, which declined by over 1,400 cases. Also, by helping the San Augustine County Lumber Company (SACLC) conduct their own anti-malaria campaign, SSW is reported to have earned an additional $30,000 in 1917 alone (Hovenberg, 1918). On March 31, 1921, four years after the initial malaria work had begun, the secretary and treasurer of SACLC, Mr. E. L. Kurth, was still full of praise for the work and wrote: "…we have a town of approximately 1,000 inhabitants and by actual canvass made last November, there were only about three percent who professed to have had malaria during the season. This works very much to the efficiency of our employes, and we think pays for the very small expense many times over" (SSW, 1921: fn. 5, 12).

IV Analysis

The cases above yield important insights regarding successful, firm-led malaria prevention. First, the people responsible for prevention in each case knew how to prevent

[44] This is a reduction in malaria patients of about 60%.

malaria, due to their own knowledge of malaria and through the help of public health officials. This explains why firm-led malaria prevention takes place in the early twentieth century and not before; the epidemiological connection between malaria and mosquitos was only shown to exist around 1897 by Ronald Ross. The person in charge of the campaign in Roanoke Rapids, Dr. Long, knew of and was inspired by the anti-malarial work conducted along the Panama Canal. It is also clear that Edwin Gould and his sanitary engineer knew of the case in Roanoke Rapids, among others (SSW, 1921). In these cases, knowing how to prevent malaria was not a constraint. Thus, both prevention campaigns focused on similar means to kill mosquitos; they drained, ditched, and oiled streams and ponds, and cleared weeds and underbrush.

Relatedly, while it is typically assumed that obtaining private health information is costly, company leaders knew which group of the larger population was most heavily affected by malaria; the group most affected by malaria included workers of the firms. In the Roanoke Rapids case, firm leaders realized their workers were absent and less productive than they otherwise could have been. Furthermore, it seems to be the case that people living in and around Rosemary village were less affected by malaria; the difference in prevalence gave mill leaders a better idea of where to focus their efforts. For SSW, it was clear that section men, bridge builders, and extra gang members, comprised larger portions of hospital cases. These groups also happened to comprise significant portions of the total population in each town.

Second, each case had interested and willing owners and managers. The profit motive, generated by the firm's respective products, was a particularly relevant motive

for preventing malaria. Norms of welfare and paternalism also played a part. Firm leaders were concerned with the health and living conditions of their workers, as was common for the time (see, for example, Scott, 1985; and Leiter et al, 1991). In Roanoke Rapids at least, villages were established and associated with specific mills; this suggests firm leaders knew which workers they were protecting and that the campaign would affect most of them equally, more or less. In both cases, the owners realized malaria was a burden, set aside or even created income to finance a campaign, and positioned relevant experts to carry them out. While the companies in Roanoke Rapids transferred income to the malaria fund, a trust was created by Gould in SSW to combat malaria. Similarly, the owners had the foresight to hire managers and specialists to maintain or improve worker health. Dr. Long was hired as a company physician, but later became the person in charge of the anti-malarial campaign. Hovenberg, however, was hired shortly after SSW began its campaign in order to organize their work, which he carried out until at least 1926. These positions are indicative of the ability of firms to address and overcome the organization and monitoring problems of malaria prevention.

Third, explicit or implicit contracting, between individuals, firms, and municipal governments, helped to clearly define property rights.[45] In both cases, it was necessary to hire laborers, as well managers, to actually produce malaria prevention. The role of contracts seems to have played a prominent role in SSW, as there was a larger extent to

[45] The importance of institutions like property rights and contracts here is similar to Troesken's (2015) analysis of private and public water companies in the United States, which helped to lower typhoid morbidity in the nineteenth and early twentieth centuries.

which free-riding was possible.[46] Despite the potential for free-riding, SSW was able to contract with laborers, firms, and municipalities to provide prevention. This primarily took the form of a group of laborers, monitored by a foreman; this group was later made into a permanent department of the railroad, headed by a sanitary engineer, a general officer of the railroad.[47] Furthermore, SSW formed agreements with lumber companies and municipal governments, defined property rights, and divided the cost of malaria work so that each party was made better off. In Roanoke Rapids, inspection was also a necessary component of anti-malarial work. Regarding contracts between firms in Roanoke Rapids, however, it is likely that explicit contracts weren't necessary because Samuel Patterson was an officer of multiple mills. Because he was particularly concerned with the health of all his workers, there was little need to explicitly delineate property rights amongst the firms. Thus, Patterson and Dr. Long were able to cooperate with each other and organize the necessary anti-malaria work.

While not discussed above, the firm's ownership of employee housing influenced malaria prevention in important ways. First, it lowered the transaction costs, as well as the free-riding problem, associated with making separate agreements with each homeowner. By the firm's ownership of such property malaria prevention was more easily provided. Second, with ownership of housing in the firm's hands, employees could be required to maintain their property according to standard rules that aided malaria prevention. Finally, as homes and land increase in value with malaria prevention, the firm

[46] SSW operations spanned over thousands of miles, employed thousands of workers, and involved numerous firms and municipalities throughout eastern Texas; thus there is more of an opportunity to free-ride.

[47] Sautet (2000) suggests the formation of a division is normal for larger firms of the era, as well as an entrepreneurial solution to the complex problems posed by malaria prevention.

and residents became residual claimants over these assets. All of these factors could have helped to align incentives that facilitated malaria prevention.

In particular, individual and section/row houses were available in both cases, but boarding houses and dormitories were also used by the firms in Roanoke Rapids. In Roanoke Rapids, boarding houses and dormitories would have significantly reduced the transaction costs of gaining consent, as well as the monitoring costs associated with administering an anti-malaria campaign over multiple locations. While waterways did cross through the villages, most of the anti-malaria work took place outside of the villages and closer to the main rivers and streams. The mill companies also housed supervisors and overseers in separate houses, which is a kind of non-monetary incentive to encourage performance. Also, the mills would have retained the value of their employee residences after sale, as is suggested in an application of the Roanoke Rapids Historical District to the National Register of Historic Places, submitted in October of 1990.

Details on employee housing in SSW are less clear, but the firm did implement a campaign to clean the yards of section houses in the spring of 1921 (Hovenberg, 1926). The campaign stretched over 186 miles where company section houses were located. The best kept lawns were awarded cash prizes and paid vacations. SSW even helped finance the pavement of sidewalks. This is indicative of the use of competition amongst workers to encourage performance (Lazear and Rosen, 1981).

Fourth, firm-led prevention can encompass larger geographic areas and larger populations than might be thought possible. While the case in Roanoke Rapids suggests

that firms can prevent malaria in small towns, with populations in the thousands, the work of SSW eventually spanned across hundreds of miles, across state borders, and amongst thousands of workers and even larger populations in towns throughout Texas. The SSW campaign took place over a period of four years, not all at once. Yet, as the scale of work became larger and larger, the railroad adapted by creating a department specifically dedicated to malaria work.

Finally, the encompassing nature of the two firms suggests another channel through which firm-led prevention took place. During the 1910's, the cotton mills and railroads were significant firms in their respective towns. Roanoke Rapids developed as a city because of the cotton mills, water and electricity companies, and various other manufacturing firms. SSW was also a major firm in eastern Texas, especially for the towns it serviced. Thus, it could be argued that mill leaders like Samuel Patterson or Edwin Gould used or abused their power to influence political leaders, as well as their workers and local citizens, to force or coerce them to prevent malaria for their financial gain. There is little existing evidence to support these claims. None of the sources cited above, i.e., public health reports, medical journals, company records, newspapers, and secondary sources, give any indication that politics, let alone coercion, was a means towards malaria prevention. These sources cite motives of profit and benevolence, much like Tocqueville in his analysis of early American industry and civil society.

V The Decline of Privately Coordinated Malaria Prevention

There is little evidence of firm-led malaria prevention between the mid 1920's and the early 1950's, at which time malaria was eliminated from the United States. This section argues that firm-led prevention declined because of its declining value to firms. Specifically, this is due to the declining rate of malaria, increasing involvement from the federal government, and technological change, which all helped to lower people's exposure to mosquitos and the burden of malaria. Firms soon found property rights over malaria prevention and control less valuable.

This argument is taken, not because others are not relevant, but because it adequately develops the logic behind firm-led prevention discussed in Section II. Indeed, the cost of malaria prevention could have increased over the mid twentieth century as firms attempted to prevent malaria in places where malaria was harder to reach.[48]

5.1 The Decline of Malaria

Malaria rates began to decline around the turn of the twentieth century, which suggests that the burden of malaria became less and less of a concern. This decline is broadly consistent with the epidemiological transition all developing nations go through, whereby death rates become more and more attributable to chronic diseases of old age, instead of infectious diseases, which burden younger adults and children (Deaton, 2014). Ernest Faust (1921: 122), a renowned parasitologist, notes that "the period from 1850

[48] Such a selection effect could have increased the necessity of government financing. However, it is also the case that federal malaria prevention in the United States selected its operations in pursuit of goals related to war and economic depression, i.e. bolstering troop strength and alleviating unemployment. These goals may or may not be related to the increasing cost of malaria prevention in the early to mid twentieth century.

through 1899 may be regarded as the era when malaria developed to its climax in the United States, after which it began to diminish in intensity and in distribution." Figure 2 shows a graph of mortality and morbidity rates in 13 states, predominantly in the South, between 1920 and 1946 (Tetzlaff, 1948: 562). In 1920, the peak of this graph, the incidence of malaria is about 1,000 per 100,000 people; the incidence declines to around 100 per 100,000 by 1948. By the early 1950's, malaria had been eliminated from the United States.

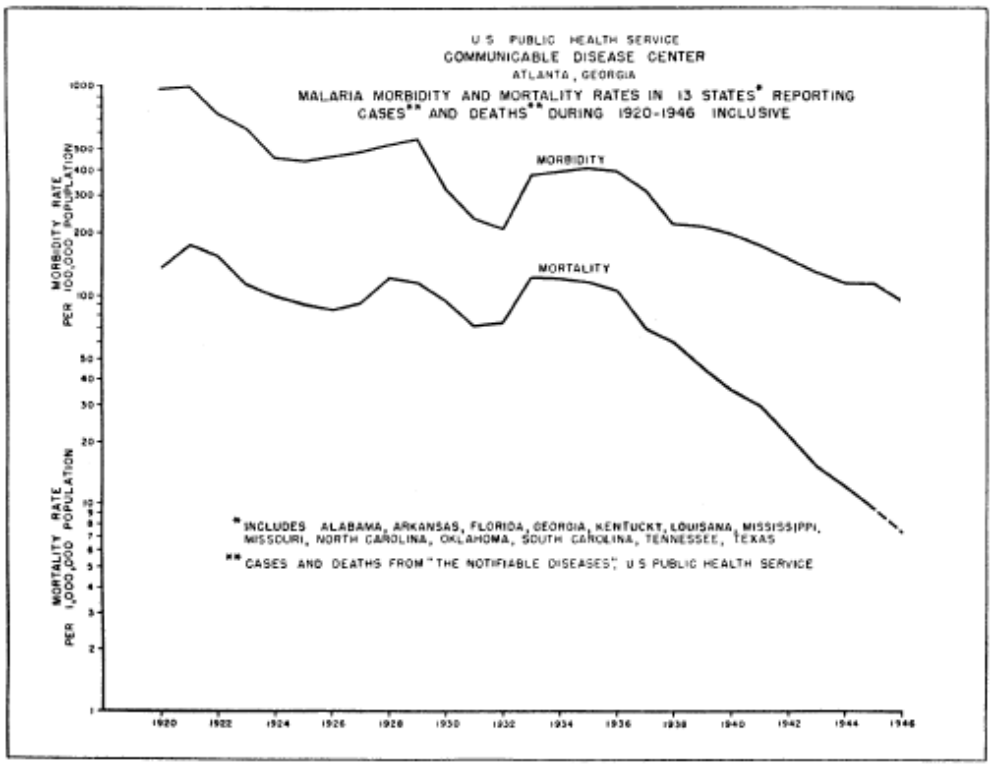


Figure 1 The Decline of Malaria in the United States
Reprinted from Tetzlaff (1948)

Technological innovations also helped to lower malaria rates by lowering people's exposure to mosquitos. Barber (1929) suggests that improvements in animal dwellings, screenings, cheaper sources of quinine, and economic prosperity all contributed to the decline in malaria and thus the value of firm-led prevention. The introduction of DDT in the 1940s, furthermore, lowered the cost of spraying, which allowed more individuals and local communities to eliminate mosquitos. Tetzlaff (1948) shows that from 1945 to 1947, the number of counties conducting residual house-spraying operations rose from 111 to 297; the number of houses sprayed rose from 264,482 to 1,236,841; and the number of pounds of DDT used rose from 103,957 to 964,449.

5.2 Increasing Government Involvement

Increasing government intervention became a substitute for firm-led prevention. When managers and firms expected state and federal governments to provide malaria prevention, it was no longer beneficial to form property rights over malaria prevention and control.

Government intervention at the federal level increased during WWI, the Great Depression, and WWII. During WWI, "successful malaria control work was carried out in 43 separate areas in 15 States (in addition to the cantonment areas themselves). Anopheles [mosquito] control has been accomplished in a total area of over 1,200 square miles" (Le Prince, 1919: 551). Le Prince also suggests these efforts helped to lower the prevalence of malaria for the civilian population of about 1,750,000 people.

The federal government again became a significant financier of malaria prevention during the Great Depression. The Depression greatly reduced wealth and hindered private and public antimalarial efforts. Faust (1951: 126) writes that "drainage projects were neglected; the economically lowest third of the population were unable to buy food, clothing, and medicine, to maintain minimum housing standards. Thus, many epidemiologic factors were favorable for the rapid increase of malaria throughout the country, and these account for the excessive amount of malaria, which reached its climax between 1933 and 1936."

Government influences on malaria incidence came from a variety of New Deal programs: the Civil Works Administration (CWA), the Works Progress Administration (WPA) and the Tennessee Valley Authority (TVA). Inadvertently, the Agricultural Adjustment Act (1933) also decreased malaria rates because it encouraged people to leave rural areas which also happened to be heavily malarious (Humphreys, 2001; Barreca, Fishback, and Kantor, 2012; Sledge and Mohler, 2013).[49] Regarding federal antimalarial programs in general, Kitron and Spielman (1989: 397) note that "some 32,000 miles of ditches were constructed during 1933-1935, draining 623,000 acres of land. On an average day, and for six and a half years, these relief programs employed 211,000 men in malaria-related efforts in 250 counties". Faust (1951: 126) suggests that, through better diets, medial care, and housing, as well as the federal government's coordination of local public-works projects focused on sanitation and mosquito spraying,

[49] Humphreys suggests this theory, Barreca et al show it empirically throughout the southern United States, while Sledge and Mohler provide contradictory evidence for Alabama.

"considerable improvement in the health of the population had been achieved by 1941" (1951: 126).

Between December of 1933 and March 1934, the CWA financed a project proposed by the Public Health Service (PHS) to dig drainage ditches in fourteen states (Williams, 1935). The CWA gave the PHS $350,000, and employed almost 14 assistant state directors, 59 district supervisors, and 212 local supervisors in December. The project supervised an average of 64,000 workers, dug almost 6,000 miles of ditches, and drained about 100,000 miles of ponds and more than 200,000 acres of swamps, all of which benefited a population of approximately 8,000,000 people. The CWA shut down in March of 1934, but antimalarial work began again after a couple of weeks under the purview of the Emergency Relief Administration and through the cooperation of state relief organizations. By December of 1934, almost all of the original CWA projects had been completed (Williams, 1935).

Regarding the Works Progress Administration, W.N. Bispham (1939: 850) notes that while large amounts of WPA funds were allocated to states and counties, there was little expert supervision and so much of the work performed was inadequate as a means for malaria prevention (see also, Humphreys, 1996). Contrary to Bispham, Kitchens (2013a) and Sledge and Mohler (2013) provide statistical evidence that WPA projects helped to lower the incidence of malaria in Georgia and Alabama. Kitchens suggests that the mortality rate in counties in Georgia that benefited from drainage projects of the WPA fell by 9.11 deaths per 100,000 persons and that these projects explain 44 percent of the overall decline of malaria deaths between 1936 and 1940. Sledge and Mohler

suggest that the drainage projects of the WPA in Alabama reduced the average number of deaths from 274 to 237.

As for the Tennessee Valley Authority (TVA), it apparently had mixed effects. It allocated much of its budget towards anti-malarial projects that included drainage work, clearing brush, oiling, larvicide, and introducing natural predators of mosquitos. The TVA even constructed dams to increase the height of water levels in reservoirs, which killed their tendency to promote mosquito-breeding sites (Bishop, 1935). However, damming creates reservoirs and additional shoreline, which, as Kitchens (2013b) shows, actually increased malaria rates. In Alabama and Tennessee, Kitchens estimates, TVA operations increased mortality rates by 2.8-4.4 deaths per 100,000 people and increased morbidity rates between 7.1 and 13.9 cases per 100,000 people.

The federal government continued to be a major provider of malaria prevention as the United States entered WWII (see, in general, Office of the Surgeon General, 1963). At first, the federal government coordinated prevention to protect the health of soldiers because tens of thousands of Northern troops began to train in the South, an area in which malaria was endemic. In 1942, the PHS obtained funds to rid the South of malaria and created the Malaria Control in War Areas (MCWA) program, which operated in military bases and locations essential to the war effort. The MCWA established approximately 900 mosquito-control operations in 1942 and 1,161 by 1943; these operations took place in over 317 counties in twenty-one states, the District of Colombia, and Puerto Rico (Parascandola, 1996). According to Faust (1951: 126),

The military forces of the Federal Government instituted strict antimalarial measures within the confines of the military camps, and Public Health Service and local health agencies combined to control mosquito breeding in the immediate environs of the camps. These joint efforts were soon effective in keeping malaria at a minimum within the military establishments and were also, to an increasing degree, reducing malaria in the civilian population living on the periphery of the camps.

Overall, Tetzlaff (1948) notes, about 2,200 war establishments were protected against malaria during the program's peak of operations. As the war drew to a close, the federal government continued its role as antimalarial coordinator because of the fear that malaria would reemerge in the United States from returning soldiers. Thus,

> The emphasis from war establishment malaria control, a program intended primarily to prevent the spread of malaria into military and war establishments from surrounding areas where malaria was prevalent, has been shifted to the protection of the civilian population from malaria brought in by returning military personnel. The latter program, known as the extended program, involved the extension of malaria control activities from the immediate vicinity of purely war-important areas to all areas of relatively high malaria endemicity" (Teztlaff, 1948: 558).

As Parascandola (1996) suggests, this organization evolved into the Communicable Disease Center, which continued to coordinate malaria prevention until the disease was eliminated in the early 1950's.

Given the growth of federal malaria prevention throughout the first part of the twentieth century, the benefits of firm-led prevention declined. Thus, it was rational to forego the costs of firm-led prevention. Firm leaders would have expected the incidence of malaria to decline, in part, due to involvement from the federal government.

VI Conclusion

In examining the history of malaria in the United States, St. Louis Southwestern Railway and the various mills and other companies of Roanoke Rapids deserve attention and explanation. In the 1910's, shortly after the burden of malaria was at its peak in the United States, but still burdensome, these firms successfully prevented malaria for the benefit of their workers, the local population, and their profits. Firms provided these goods because they were the residual claimants and because they could do so cheaply. These cases of firm-led prevention represent successful alternative means of prevention that economists and public health experts can learn from. In particular, these cases suggest that the institutions, such as the organizational structure of a firm, the different means of contracting, and the forms of property rights, can an important determinant in disease prevention. Indeed, while it may be costly for a firm to prevent a disease like malaria, due to issues of uncertainty and monitoring, the firm can overcome such costs if the benefits are high.

A number of general conditions were particularly important in these cases. Firm-led prevention took place when people knew how to prevent the disease, and when information of the relevant population was easily obtainable. Firms provided malaria

prevention when the owner of a firm faced incentives to finance it and when managers and workers faced incentives to carry out the desires of the owner. Furthermore, these cases suggest that geography and population size need not be severely limiting for firm-led prevention. To the extent firms and larger corporations cover large areas and employ large groups of people, they can also organize appropriate monitoring mechanisms to provide public health goods like malaria prevention campaigns.

These cases also raise interesting implications for the relationship between firms and public health agencies. That is, both firms and public agents were involved in producing the ultimate prevention campaigns we observed in Roanoke Rapids and in eastern Texas. The cases were not entirely private, as public health officers of the US Public Health Service provided relevant information regarding the epidemiology of malaria, as well as surveys and data on prevalence rates. This service helped to lower transaction costs for malaria prevention in general. Yet, to the extent the owners had the foresight to hire doctors to maintain employee health, to build hospitals and hire sanitary engineers, and to request public health officials to survey the malaria problem, it suggests the firms were actively taking steps towards prevention. At the very least, there is an interesting admixture of private and public entities both with interests in preventing malaria.

Finally, if people are burdened by malaria and their local and state public health services are weak or failing, as was the case in the United States prior to the late 1910's, firms can fill a gap in the provision of malaria. People need not rely exclusively on

government for malaria prevention. If governments do begin to prevent malaria, however, it is likely that firms will no longer find it beneficial to provide similar services.

CHAPTER THREE

I Introduction

The 2014-2015 Ebola epidemic offers a unique opportunity to illustrate how private-sector firms respond to severe epidemiological disasters. The Ebola virus disease spreads from person to person contact, through blood and other bodily fluids, contaminated objects like needles, the touching of a deceased person, as well as from infected fruit bats and primates. It is well known that firms can help provide goods and services related to public health, especially if an infectious disease is known or is endemic. For example, Fishback (1992), Troesken (2015), and Carson (2016) discuss how private sector firms provided sanitation, water filtration, and anti-malaria campaigns in the United States during the late 19th and early 20th centuries. Firms have helped to prevent malaria in Ghana and South Africa (Ebama and Urbach, 2011), as well as in Zimbabwe and Zambia (Watson, 1953; Utzinger et al., 2001). Firms in South Africa have even provided a variety of services to care for and treat HIV-positive patients and, likewise, to prevent its spread (Rosen and Simon, 2003; Borzel and Thauer, 2013). With the recent Ebola epidemic, however, there was less time to prepare and its trajectory was unprecedented, as past outbreaks – while numerous – were smaller and easier to contain (Chippaux, 2014; Peters and LeDuc, 1999; and Shears and O'Dempsey, 2015).

This paper provides an economics-based explanation as to why large industrial firms in Liberia responded to the Ebola epidemic by altering their organizational structures and production processes. At least 11 firms in the mining, agricultural, and oil and gas industries undertook Ebola prevention to maintain the health and productivity of their workers, their dependents, and members of the local community. They did so because their property rights were well-defined and enforced through their concession agreements with the Liberian government and because prevention was profitable. Most of the firms reported zero cases of Ebola, whereas - according to the Ebola case counts of the World Health Organization's patient database – the number of confirmed cases across the fifteen counties ranged from a low of 3 (Grand Gedeh) to a high of 1,978 (Montserrado), with an average of 138. Taking the highest and lowest counties out, the number of cases ranges from a low of 4 (Maryland) to a high of 400 (Margibi), with an average of 104. Table 1 lists major firms in Liberia.

Table 2. Largest Firms with Concession Agreements in Liberia, by tax burden

Firm	Industry	% of government revenue from industry (2014)
Arcelor Mittal Liberia	Mining	57.35
China Union	Mining	15.93
Putu Iron Ore Mining Inc.	Mining	7.39
Western Cluster Limited	Mining	4.20
BHP Biliton	Mining	3.49
Bea Mountain Mining Corporation	Mining	3.18
Boart Longyear Corporation Liberia	Mining	2.22
Amlib United Minerals Inc.	Mining	1.73
Hummingbird Resources Inc.	Mining	0.88
Steinbock Minerals	Mining	0.69
Jonah Capital (BVI) Liberia Ltd.	Mining	0.48
Earthsource Mineral International	Mining	0.27
Anglo American Kumba Exploration	Mining	0.22
West Africa Gold and Diamond	Mining	0.19
Iron Resources Liberia Ltd.	Mining	0.17
Firestone Liberia Incorporated	Agriculture	35.19
Liberian Agricultural Company	Agriculture	20.44
Golden Veroleum Liberia	Agriculture	9.61
Sime Darby Plantation	Agriculture	9.15
Salala Rubber Corporation	Agriculture	8.94
Cavalla Rubber Corporation	Agriculture	7.62
Libinc Oil Palm Inc.	Agriculture	4.31
Maryland Oil Palm Plantation	Agriculture	1.86
Equatorial Palm Oil Incorporated	Agriculture	1.15
The Lee Group of Enterprise	Agriculture	0.96
Liberia Forest Products Inc.	Agriculture	0.61
Chevron Liberia Ltd.	Oil and Gas	43.88
Anadarko	Oil and Gas	40.88
ExxonMobil	Oil and Gas	8.39
European Hydrocarbon Ltd.	Oil and Gas	6.45

Source: Liberia Extractive Industries Transparency Initiative (LEITI)

Understanding the private sector's response to epidemiological disasters complements the economic approach to epidemiology (Laxminarayan and Malani, 2011; Philipson, 2000; and Roberts, 2006). The notion of "prevalence elasticity" or responsiveness to a changing prevalence rate (Philipson and Posner, 1993; 1995), is extended to human behavior within a firm. While most studies of prevalence elasticity focus on changes in the consumption of potentially preventive behavior, e.g., the

consumption of vaccines (Goldstein et al., 1996; and Oster, 2016), and the variety of HIV/AIDS-related behaviors (Kremer, 1996; Oster, 2012; Greenwood et al., 2016), the way in which people respond collectively to infectious diseases in the context of a private-sector firm is underexplored. Yet, prevalence elastic behavior in a firm, or firm-led disease prevention, was an important response to the epidemic in some parts of Liberia.

Firm-led Ebola prevention complements our understanding of when and how private and social goals align to resolve collective action problems associated with infectious diseases. Whenever people prevent the spread of an infectious disease, they confer external benefits on others, thus raising the prospect of the well-known free rider problem (Gersovitz and Hammer, 2003; Tullock, 1969). Resolving externality problems of infectious diseases is particularly problematic for uncoordinated private actors. However, Adam Smith noted long ago that private actors at least partially mitigate external effects when profit opportunities exist. Historical, theoretical, and experimental analyses of the private provision of public goods support Smith's insight (Anderson and Hill, 2004; Beito et al., 2009; Bogart, 2005; Brubaker, 1975; Coase, 1974; Cheung, 1973; Cornes and Sandler, 1996; Demsetz, 1970; Foldvary, 1994; Harrison and Hirshleifer, 1989; Klein, 1990; Smith, 1980; Skarbek, 2014).

Furthermore, firm-led disease prevention highlights a potential pathway through which institutions and infectious diseases influence economic development. Bloom and Sachs (1998) suggest poor health is a primary determinant of economic development. Madsen (2016) argues parasitic diseases and iron deficiencies impair cognitive

development, which deters human capital formation and the level and pace of economic development. Acemoglu, Johnson, and Robinson (2003), however, argue that the effect health has on differences in wealth is small. Young (2005) even argues that while HIV lowers the likelihood of acquiring human capital, its effect is offset by lowering fertility, which enhances consumption possibilities in South Africa. For further discussion on the relationship between health outcomes and economic development, see Acemoglu and Johnson (2007), Bloom et al. (2014), and Acemoglu and Johnson (2014). Bhattacharyya (2009) develops a unifying framework that distinguishes between the importance of diseases and institutions in the early and late phases of development, respectively. Yet, these scholars have underexplored the role firms have in disease prevention. That is, firms establish financial incentives to alter the epidemiological, ecological, and behavioral conditions that facilitate disease transmission, which can lower prevalence rates and positively influence long-term economic development.

Finally, studies on the economic, political, and social determinants of Ebola largely ignore private firms (Alexander et al., 2015; Manguvo and Mafuvadze, 2015; Tambo, 2015; Abramowitz et al., 2015; Salmon et al., 2015; Richards et al., 2015; Regmi et al., 2015; Kalra et al., 2015; Leach and Scoones, 2013; and Fallah et al., 2015). Bowles et al. (2015) shows that Liberian firms in the automotive, construction, food and beverage, and restaurant industries, as well as others in the capital of Monrovia, responded to the epidemic by closing down. These firms, typically small businesses with fewer than ten employees, faced temporary declines in revenue and could not have afforded to undertake a meaningful prevention campaign. Larger firms walked away too;

Wilkinson and Leach (2014) dismiss the private sector's response to Ebola based on the exit of larger firms like London Mining and British Airways.

Private firms also are believed to contribute to the spread of Ebola. While complex political economy factors influence the interactions between a nation's economic interests and its agroecology, larger firms and business-oriented government policies encroach upon forestlands, bringing people closer to reservoirs of disease (Wallace et al., 2014; Wallace et al., 2016; and Wallace and Wallace, 2016). Leach (2015) suggests that long term economic and political structures of violence cause income inequality, environmental problems, and conflict. Local populations around larger firms supposedly fail to develop inclusive political, economic, and public health institutions because of the company's pursuit of profit (Allouche, 2015; Leach, 2015). On the contrary, this paper focuses on the incentives firms have to halt the transmission of Ebola. That is, while firms can be a cause of epidemics, they also can represent a means of prevention.

II Property Rights, Profit, and Firm-led Disease Prevention

Preventing contagion emits a positive externality because people are automatically better off through a lower probability of infection. Therefore, an uncoordinated group of people suffer from a collective action problem, whereby individuals free-ride on the preventive actions of others. Over time, this leaves an uncoordinated group of people with too little prevention, which facilitates disease

transmission. Mitigating this problem requires a mechanism to punish free-riding or reward cooperative prevention activities.

Philipson and Posner (1993) develop an epidemiological model based on individual behavior, whereby people respond to changes in disease prevalence by altering their consumption of infectious or preventive behaviors. While individuals may not resolve the collective action problem completely by fully internalizing the externalities, they can mitigate an epidemic's severity by the extent to which individuals respond to changes in the costs and benefits of disease prevention.

People can respond to changes in prevalence along multiple margins, of which leveraging the financial resources and organizational capacity of a firm is of particular interest. As prevalence rates increase, the incentives of owners and managers to moderate the impacts on their enterprises become stronger, inducing them to discover ways of lowering rates of employee absenteeism caused by their own sickness or the need to care for infected family members. They can respond by purchasing medical supplies, employing doctors and relevant public health specialists, restricting entry to a worksite, or enforcing public health rules like the use of facemasks.

Firms facilitate prevention by coordinating these actions and aligning incentives. The owner is a residual claimant of the firm and, to the extent that a firm's value depends on healthy workers – healthier workers are more productive, take less sick leave, and are less likely to die – she faces financial incentives to prevent the spread of an infectious disease. Providing prevention requires the help of many people, which suggests that the owner must contract with subordinates and workers. That is, following Barzel (1997),

larger, more complex production plans require the exchange of property rights. Individual workers also have incentives to cooperate given that their own health and future wealth are at stake.

Conditions under which a firm is expected to respond to the outbreak of an epidemic can be identified. The primary factor of firm-led disease prevention is the extent to which property rights are well-defined and enforced. Well-defined and -enforced systems of property rights are known to give people incentives to innovate and make long-term plans (North, 1990; and Troesken, 2015). The more an owner of a firm holds property rights over future income streams, secure from the expropriation of private and public actors, the more she cares for workers and will act to ensure their health and safety. Furthermore, the quality of institutions is a critical factor in how well property rights are defined and enforced. If rights are subject to arbitrary enforcement or renegotiation, however, private actors have less incentive to engage in market activity (Estache and Wren-Lewis, 2009).

Assuming property rights motivate a firm to innovate and care for their workers, firms must also expect to earn profit, regardless of the epidemic shock, and they must find the marginal benefit of prevention greater than its marginal cost. If firms had little expectation of profit, *prevalence-inelastic* behavior would be driven by conditions unrelated to changes in prevalence rates. For example, London Mining and African Minerals, iron producers in Sierra Leone, had long faced a declining price of iron, rising debt, larger interest payments, and production setbacks (Ficenec, 2014; Guthrie, 2014; Armstrong, 2014; Wilson and Hume, 2014; Wilson, 2014a). Furthermore, Google

Finance shows a downward trend in the stock prices for both companies, which began years before the Ebola epidemic. For other firms, prevention was too costly. For example, smaller Liberian firms shut their doors during the epidemic (Bowles et al., 2015). Ninety-six per cent of Liberian businesses employ less than fifty workers (Musinamwana and Togba, 2014). That kind of response (i.e., *prevalence elastic* behavior) plainly has a negligible influence on prevalence rates because these firms did not implement preventative measures. Also, that response does not illustrate how some firms can aid in prevention. This paper focuses on firms that expect to remain in business, firms with larger workforces, and firms with workers who face higher probabilities of infection.

Thus, private actors, from individuals to large firms, are expected to respond to outbreaks when property rights are well-defined and –enforced, when they are financially motivated to do so, and when the marginal benefit exceeds the marginal cost. When these conditions hold – so that firm-led disease prevention is valuable – the owner or manager of a firm implements a prevention campaign, which lowers disease prevalence around the firm. Complementary factors of prevention, discussed below, include the relative scarcity of labor and public health alternatives. Finally, parametric insurance and risk analysis also facilitate firm-led prevention. But as participants of the *Global Health Risk Framework* workshop on pandemic financing suggest, these factors were not relevant prior to the 2014 epidemic because the epidemic was wholly unexpected and clear triggers may not have been available; neither buyers nor sellers valued insuring against the Ebola epidemic (Buckley and Pittluck, 2016).

3 Property Rights in Liberia

Throughout the Twentieth century, indigenous Liberians relied on traditional or customary property rights to protect their lands and settle disputes. Dalton (1963) suggests that conflict stems from the exclusion of non-elites from the political process, which keeps harmful rules in place. Stickler and Huntington (2015) suggest that many Liberians believe that tribal leaders own a majority of community property; they fear encroachment from their neighbors or cannot define boundaries clearly; and they do not have the ability to sell property or even use it as collateral.

These disputes were compounded during and after the Liberian civil wars (1989-1996; 1999-2003) by conflicts between owners of land who were displaced and people who claimed their land while the owners were absent. On the basis of field work studying conflict and how people acquire property rights over forests, Wily (2007) suggests that individuals rarely know if they or other parties will maintain the value of property. The difficulty of finding and understanding relevant laws also contributes to the complexity. People have even sold their lands to multiple parties because they knew that the threat of prosecution was negligible (Unruh, 2009). Furthermore, the Liberian state often grants rights over forests and community lands to other parties because they are considered to be in the public domain (Stevens, 2014; Wily 2011; Joireman and Yoder, 2016).

Property rights remain uncertain despite efforts to reform, namely the Community Rights Law with Respect to Forest Lands (2009), a Land Rights Policy (USAID, 2013), and other commissions by which communities are given legal standing (Johnson-Sirleaf, 2007; Wily, 2011). However, missing a court date is a common way of disrupting the

legal process, which lengthens the time and raises the opportunity costs of resolving disputes. Given the prevalence of conflict and legal disputes – conflict is a ubiquitous part of life in Liberia – accessing formal institutions of justice are too costly for most people. Indeed, *sassywood* is a common, informal means of resolving conflict throughout Liberia (Leeson and Coyne, 2012). Hilson and Bockstael (2012) suggest that current mining regulations and licensure laws deter many from mining in Bomi. Some people may take initial steps to secure property rights or mitigate conflict, but most do not complete the complex process (Corriveau-Bourque, 2010). Because of these unresolved conflicts, "the resulting insecurity of claim, residence, food supply, and investments (small and large) is high" (Unruh 2009: 427).

Relative to individual Liberians, larger firms have clearer property rights as they can enter into concession agreements with the Liberian government. Dating back to at least the nineteenth century (Stevens, 2014), these agreements encourage owners and managers to invest and innovate, at the expense of taxes and other fees the host government deems necessary. Concessions grant firms the authority to provide police services and stipulate the provision of public health services like clean water and sanitation, as well as primary medical care to their workers. Since the post-civil war reform efforts, Liberian regulatory agencies like the National Oil Company of Liberia, the Ministry of Agriculture, the Forestry Development Authority, and the Ministry of Lands, Mines, and Energy are responsible for granting concessions and enforcing them. Organizations like the Extractive Industries Transparency Initiative and the Liberia Extractive Transparency Initiative (LEITI) also help regulating agencies monitor and

enforce concession agreements. Table 2 lists the major firms in Liberia, the kind of concession agreement held, its date of issue, and its date of expiration. Due to a lack of information on firms with timber concessions, they are not included in the lists above.

Most concession terms last for a period of 25 years, while agricultural concessions last the longest – sometimes five or six decades. Based on this factor alone, agricultural concessions should be more responsive to outbreaks. With assurances from the Liberian government, the owners and managers of these concessions face incentives to invest in their respective production processes, which includes the health and wellbeing of their workers, families, and local populations. These rights also give owners and managers a long-term perspective and foster norms of trust (Taylor, 1987), which facilitate the production of local public goods like disease prevention. Alan Knight, General Manager of Corporate Responsibility with ArcelorMittal, believes the concessions give managers and owners a long-term time horizon, from which they are motivated to care for their workers (Personal Interview, May 17, 2016). Knight also presented testimony to the Senate Foreign Relations Committee, Subcommittee on Africa and Global Health on April 7, 2016.

Table 3. Concession Agreements in Liberia

Firm	Type of concession	Issue Date	Expiration Date
Mining			
Arcelor Mittal Liberia***	MDA	10/9/05	2030(2055)
China Union***	MDA	19/01/09	2034
Putu Iron Ore Mining Inc.**	MDA	2010	2035
Western Cluster Limited**	MDA	22/08/11	2036
BHP Biliton**	MDA	11/05/05	n/a
Bea Mountain Mining Corporation (subsidiary of Aureus, now Avesoro) ***	MDA	28/11/01	2026
Boart Longyear Corporation Liberia*			
Amlib United Minerals Inc*	MDA	14/03/02	2027
Hummingbird Resources (Liberia) Inc.**	Exploration	11/8/08	11/8/11
Steinbock Liberia**			
Jonah Capital (BVI) Liberia Ltd.**	Exploration	14/07/11	14/07/14
Earthsource Mineral International*			
Anglo American Kumba Exploration**			
West Africa Gold and Diamond*			
Iron Resources Liberia Ltd.*			
Agriculture			
Firestone Liberia Incorporated***	Concession	31/3/08	2041
Liberian Agricultural Company*			
Golden Veroleum Liberia***	Concession	1/09/2010	2075
Sime Darby Plantation***	Concession	30/4/09	2072
Salala Rubber Corporation***	Concession	30/08/1959	2030
Cavalla Rubber Corporation***	Concession	21/01/11	2061
Libinc Oil Palm Inc.*	Concession	22/05/08	2051
Maryland Oil Palm Plantation***	Concession	3/3/11	2036
Equatorial Palm Oil Incorporated***	Concession	2008	2058
The Lee Group of Enterprise*			
Liberia Forest Products Inc.*	Concession	22/05/08	2058
Oil and Gas			
Chevron Liberia Ltd.***	PSC	2009	
Anadarko**	PSC	2009	2016
ExxonMobil**	PSC	2013	
European Hydrocarbon Ltd. (owns African Petroleum Corporation Ltd.)**	PSC	2008	2012(2018)

MDA=Mining Development Agreement; PSC= Production Sharing Contract; FMC=Forestry Management Contract; *Little information available; **Does not meet precondition; ***Responded to the Ebola epidemic

While these firms have stronger property rights than individual Liberians, they are still uncertain. Concession agreements may be prone to arbitrary enforcement and renegotiation via the Liberian government and its regulatory bodies. One source of

confusion is the state's ability to simultaneously grant land and resources to a firm via concession and infringe upon that concession by allowing access to local communities (Unruh, 2009). Another source of confusion is the inability to demarcate large tracts of land between concession agreements and local communities, tribal land, and state and public land. For example, the total area granted in some concessions may exceed the total area of the county in which it is located (Unruh, 2009). While there are uncertainties regarding the definition and enforcement of concessionary property rights, they are more certain than the rights individuals have. Indeed, larger firms have financial motivations to resolve these uncertainties.

4 Firm-led Ebola Prevention

Of the 30 firms in Table 2, 11 responded to the Ebola epidemic by providing a prevention campaign amongst its workers and local communities. These firms account for over 75 per cent of government revenue from the mining industry, over 73 per cent of government revenue from the agricultural industry, and over 43 per cent of government revenue from the oil and gas industry. Table 3 presents a list of the responsive firms and summary information regarding their prevention efforts.

Table 4. Responsive Firms in Liberia

Firm	Location	Area (Acres)	Cases	Deaths	Employees	Response
Arcelor Mittal	Nimba, Bong, & Grand Bassa	168,921	3	1	2,498	Ebola training; health clinics with PPEs; single-entry access; ETUs; hand-washing stations; contact tracing
China Union	Bong	59,000	Not reported		<300	Checkpoints; temperature monitoring; hand-washing stations
Bea Mountain Mining Corporation (subsidiary of Aureus, now Avesoro)	New Liberty, Grand Cape Mount	112,927-250,317	0	0	1,500	Ebola training; checkpoints; temperature monitoring; health clinics; travel restrictions
Firestone	Harbel, Margibi	118,990	72	33	20,000	Ebola training; ETU; triage; patient reintegration
Golden Veroleum Liberia	Sinoe, Grand Kru, Maryland, River Gee, & River Cess	200,000 hectares	0	0	3,400	Ebola training; temperature monitoring; door-to-door campaign; new hunting policy; awareness roadshow; rehabilitated water pumps
Sime Darby Plantation	Bomi & Grand Cape Mount;	220,000 hectares	0	0	2,881	Health clinics with PPEs; Ebola training; door-to-door campaign; medical supplies; contact tracing
Salala Rubber Corporation	Salala, Bong; Margibi	100,000	Not reported		1,000	Ebola training; health clinic
Cavalla Rubber Corporation	Pleebo, Maryland	67,500	0	0	>3,000 (with Maryland Oil Palm Plantation)	PPEs; Ebola training; Ebola flyers; checkpoints; temperature monitoring; hand sanitizer
Maryland	Pleebo,	22,000	0	0	>3,000 (with	PPEs; Ebola

Oil Palm Plantation	Maryland				Cavalla Rubber Corporation)	training; Ebola flyers; checkpoints; temperature monitoring; hand sanitizer
Equatorial Palm Oil Incorporated	Palm Bay, Grand Bassa; Butaw, Sinoe	20,078	0	0	1,500	Checkpoints and temperature readings; hand-washing stations; health clinics with PPEs
Chevron Liberia Ltd.	Coastal blocks, near Buchanan and Monrovia	n/a	Not reported		300	Ebola training; provided PPEs, healthcare staff, and humanitarian aid

PPE=personal protective equipment; ETU=Ebola Treatment Unit

The firms in Table 3 provided similar goods and services, mainly related to education, disease control, and healthcare. An integral part of any prevention campaign is to inform people how infectious diseases spread; with information regarding the etiology and epidemiology of a disease, people can take preventative measures. These firms learned how Ebola spread and hired epidemiologists and other relevant public health experts to inform their workers, their dependents, and members of local communities. Lectures, for the workforce and the public, informed and eased people's fears of Ebola. Arcelor Mittal and Firestone, for example, hired Adriano Duse, an epidemiologist and expert in tropical diseases to inform their workers and assuage fears. Appendix II provides more information about the responses from Firestone, Sime Darby, and Arcelor Mittal.

Control efforts varied, from limiting access to single-entry checkpoints to coordinating contact-tracing campaigns. Firms monitored easily observable symptoms, like temperature, at single-entry checkpoints. With the aid of a thermo-flash scanner, for

example, checkpoint guards took every person's temperature as they entered a worksite. Some firms measured temperatures at regular intervals. Additional medical exams were conducted for people suspected of infection and triage procedures were established in conjunction with quarantine stations, Ebola Treatment Units, and the firm's healthcare services. The firms provided hand-washing stations with chlorine and bleach at checkpoints, as well as throughout local communities. Firms also coordinated contact tracing, an inquiry into the health status of contacts of known Ebola patients to learn if they are infected or not.

If firms had Ebola patients, they would have been cared for until recovery or death. Caring for Ebola patients is supportive, not curative, and largely includes maintaining fluids, electrolytes, oxygen status, blood pressure, and treating related infections. Ebola Treatment Units were provided with the necessary medical supplies to care for patients: doctors and nurses with personal protective equipment, hospital beds, sanitizing agents, and other medicines. Some firms even helped recovered patients reintegrate back into their communities.

10 of the firms did not respond to the epidemic because they were in the early stages of development, they were not operational, or they did not expect to earn profit. Little information was available for 9 of the firms. Table 4 provides more information on the unresponsive firms.

Table 5. Unresponsive Firms with Concession Agreements in Liberia

Firms	Location	Reasons for Unresponsiveness
Putu Iron Ore Mining Inc.	Grand Gedeh	Parent company, Severstal, required additional investors to develop its operations in Liberia; financial crisis from Russian sanctions, began in March 2014
Western Cluster Limited	Bomi, Cape Mount, & Gbarpolu	Parent company, Vedanta, was exploring and conducting a feasibility study in 2014. It did not have an operational presence.
BHP Biliton	Nimba, Bong, Margibi, & Grand Bassa	Conducting exploration operation since 2005; attempted to sell Liberian operations since 2012; sold to ArcelorMittal in August 2014
Hummingbird Resources (Liberia) Inc.	Dugbe Gold Project	Operation of Dugbe mine was in development; feasibility study was being conducted; focused on mine in Mali
Steinbock Minerals	Margibi	Barite discovery in January 2014; signed a Memorandum of Understanding in March 2014, which usually precedes production. Able to meet demand from other operations.
Jonah Capital Liberia Ltd.	Bong, Nimba, & Grand Geddeh	Still in exploration phase, along with its subsidiary Cavalla Resources
Anglo American Kumba Exploration	n/a	Completed exploration study in 2014; closed operation with Jonah Capital
Anadarko	Coastal oil blocks	Relinquished leases in 2012.
ExxonMobil	Coastal oil blocks	Still in exploration phase, conducting technical evaluation; postponed planed drilling operations because of Ebola
European Hydrocarbon Ltd. (owns African Petroleum Corporation Ltd.)	Coastal oil blocks	No active operations in Liberia; offices were closed and precautionary measures were taken

5 Complementary Factors of Firm-led Disease Prevention

5.1 Relatively Scarce Labor

Firm-led disease prevention is more likely as workers become relatively scarce. Workers become relatively scarce as the labor market becomes more competitive or if fewer workers are available to hire. For example, Fishback (1992) shows that in isolated areas of the United States, coal mining companies provided sanitation services to attract workers and maintain employment. Similarly, as transaction and transportation costs

decline, workers become more mobile and knowledgeable of additional employment opportunities. Thus, a competitive firm must offer higher real wages to attract relatively scarce workers, and disease prevention can be part of a worker's total compensation.

For a variety of reasons, it may be more difficult to hire workers in rural areas of Liberia. The U. S. State Department issued an Investment Climate report on Liberia (2015: 21), which argues that one of the biggest operational hindrances foreign companies face is the difficulty of finding skilled labor. While population has risen by about 50 per cent since 2000, net migration has declined since 2010, and about half of the population lives in urban areas. For example, Monrovia is the country's largest city with around 1.2 million people, and it comprises about 30 per cent of the total population and 56 per cent of the urban population. Many Liberians also desire employment in the formal sector, largely in urban areas (Lindberg, 2014; Bonaparte, 1979). In rural areas, 75 percent of the available population remains in the informal sector, mainly as self-employed traders or farmers (Richiardi, 2015). Figure 1 and 2 show the change in population and the percentage of people living in rural areas, respectively, in Liberia between 2000 and 2015.

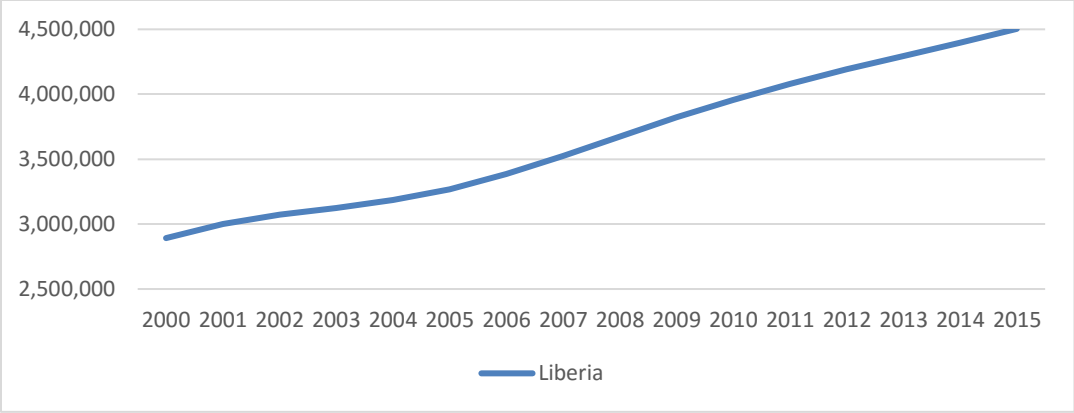


Figure 2. Total Population in Liberia, 2000-2015
Source: The World Bank (2016)

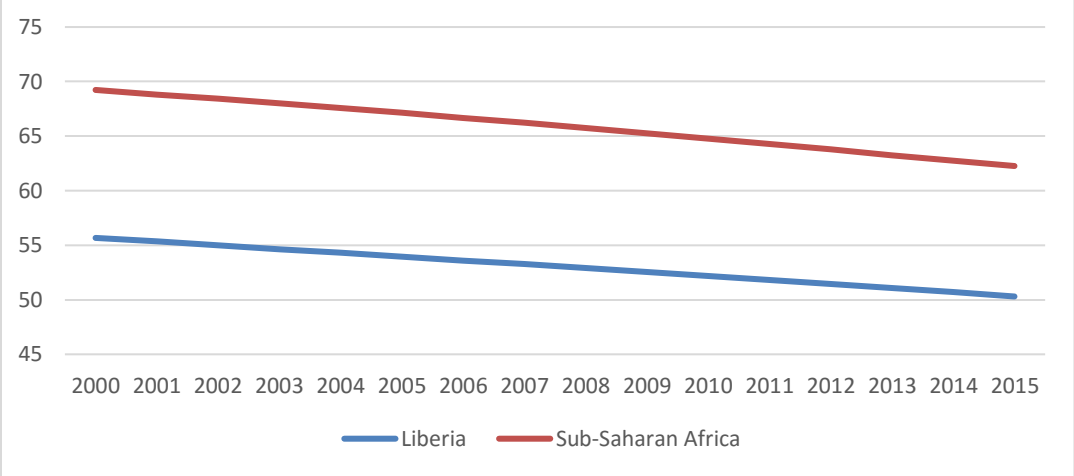


Figure 3. Rural Population (% of total) in Liberia, 2000-2015
Source: The World Bank (2016)

To the extent these factors reduce the pool of available workers, the concessionaires are more likely to offer a higher real wage to attract and retain employees.

Additionally, numerous means of transportation exist by which people can more easily move throughout the country and western Africa. The 2007 and 2013

Demographic and Health Surveys (DHS) surveys show increases in ownership of motorcycles/scooters, cars/trucks, and boats/canoes in urban and rural areas. According to the 2015 Afrobarometer survey for Liberia, about 94 percent of the respondents lives within walking distance of paid transportation services, which include busses, taxis, and mopeds (Question EA_FAC_G). Transportation networks and the various means of transportation lower transaction costs associated with moving, increase a person's outside employment opportunities, and encourage firms to offer higher real wages.

Improved communication networks lower search costs too. Figure 3 and Figure 4 show the decline in fixed telephone subscriptions and the rise of mobile telephone subscriptions, respectively, in Liberia between 2000 and 2015.

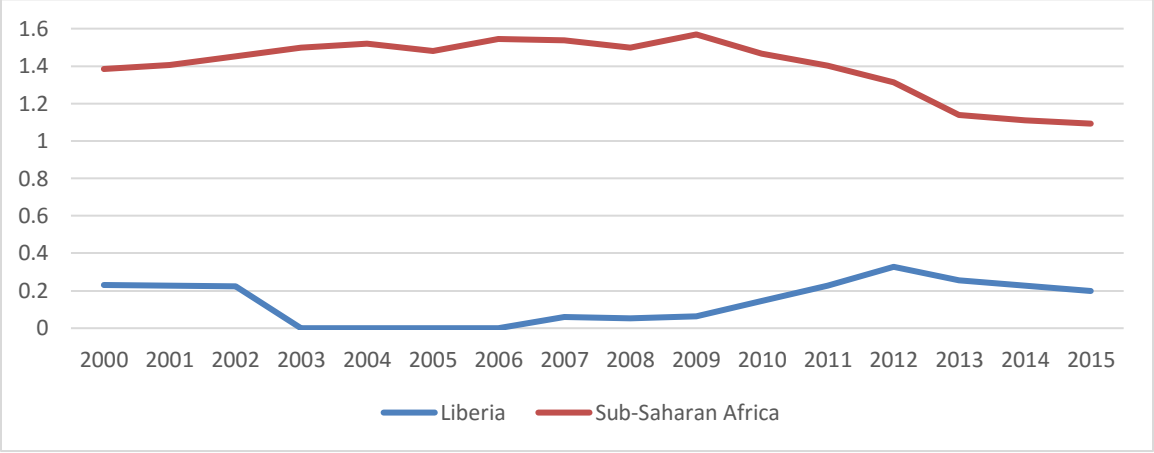


Figure 4. Fixed Telephone Subscriptions (per 100 people), 2000-2015
Source: The World Bank (2016)

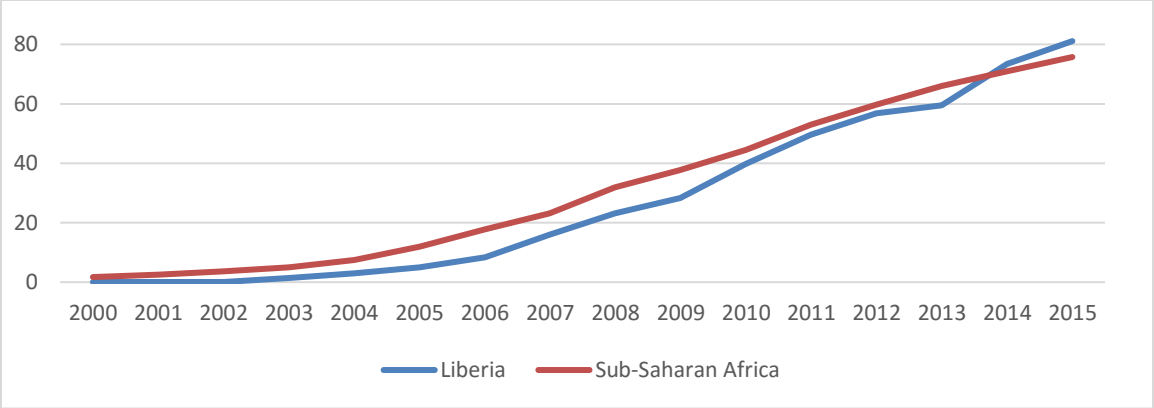


Figure 5. Mobile Phone Subscriptions (per 100 people), 2000-2015)
Source: The World Bank (2016)

Mobile phone communication is even more important given that fixed-line telephone networks were destroyed during the civil wars (Best et al., 2010) and seem to be declining in importance. Best et al. (2010) suggest that there are five users for every one mobile phone subscription. Four active mobile phone providers serve the country, which produce some of the lowest rates in the region. In interviews, Best et al. (2010) found that Liberians, both rural and urban, rely on their phones for contacting clients and learning about price differences.

Internet based forms of communication are also developing. The World Bank estimates that the number of Internet users rose, from less than 1 percent in 2007 to over 5 percent in 2014, and the number of fixed broadband subscriptions has increased from 524 in 2012 to about 6,000 in 2014. With access to more information, and lower transportation costs, it is easier to learn about which firms offer higher real wages and, if necessary, to migrate. These factors suggest that workers have the ability to compare real

wages, which bids them up. As a result, firms have incentives to pay market-determined wages. Figure 5 shows the increase in internet users in Liberia, from 2000 to 2015.

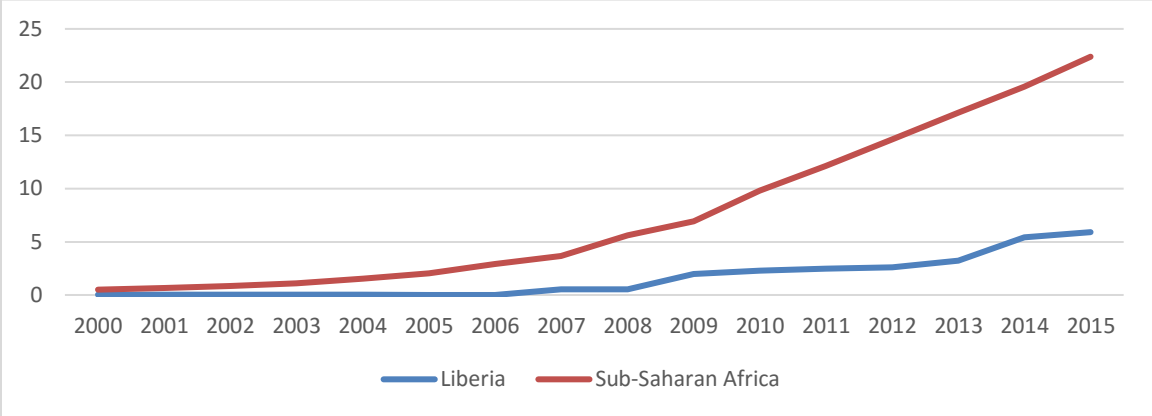


Figure 6. Internet Users (per 100 people), 2000-2015
Source: The World Bank (2016)

Firms also face incentives to lower a worker's real wage. Unemployment at the regional level seems to have increased from 2007 to 2013, indicating that workers may be willing to become employed at lower wages. In 2007, the Demographics and Health Survey reports an average unemployment rate of 33.4 percent for women across Liberia's five regions; the average was 44.7 in 2013. For men, the average unemployment rate was 14.9 in 2007, while it was 19.74 in 2013. Given that workers are willing and able to be employed, rising unemployment suggests that firms can offer lower real wages to attract and retain workers.

Conditions in particular industries also provide differing incentives. The agricultural sector employs a large percentage of Liberian workers. While the share of

agricultural workers has declined between 2007 and 2013, the 2013 Demographic and Health Survey in Liberia reports that the average employment rate in agriculture across Liberian counties is about 54 percent for women and 49 percent for men. To the extent that agricultural firms depend on the health of large fractions of the Liberian population, they face particularly strong incentives to prevent the spread of Ebola. Furthermore, firms in the mining industry contract with a variety of smaller firms like those in carpentry and welding, which suggests that they have interests in maintaining the health and productivity of workers outside of their firm.

Firms in the agricultural sector may employ different kinds of workers than firms in the mining industry, which could make them less likely to prevent Ebola. Specifically, workers in the agricultural sector are more likely to be among the poorest and less-skilled in Liberia. About 79.9, 72.6, and 51.5 per cent of women in the lowest, second, and third quintile of wealth work in agriculture, respectively. About 73.8, 65.6, and 42.8 per cent of men in the lowest, second, and third quintile of wealth work in agriculture, respectively (DHS, 2013). People in the lowest wealth quintiles also have a lower probability of completing at least secondary schooling and a higher probability of being unable to read. That is, 8, 14.5, and 27 percent of people in the lowest, second, and third quintiles of wealth have completed secondary school or higher, respectively. Among those in the lowest, second, and third quintiles of wealth, 83.8, 74.7, and 59.1 percent report that they cannot read at all (DHS, 2013).

To the extent that agricultural firms employ unskilled workers who are relatively abundant, they should be less likely to prevent Ebola as workers can be more easily

replaced if they become infected with Ebola or die. Regarding Liberia's mining industry, workers with relatively high skills are more valuable. Line cutters, for example, must have basic literacy and math skills. There are also a variety of semi-skilled opportunities, e.g., electrical, plumbing, mason, information, that mining companies contract with others (Casavant and Musinamwana, 2014). Whereas agricultural firms are more likely to hire domestic workers, mining firms are more likely to look to foreign labor markets to acquire people with better skills (Bruins, 2013).

5.2 Public Health Alternatives

Firm-led prevention is more likely as fewer public health alternatives are available, e.g., individual responses, local and state level governments, and international humanitarian organizations. For example, firm-led HIV prevention in South Africa can be attributed to the inability of its governments to respond appropriately to the growing AIDS epidemic (Borzel and Thauer, 2013). Similarly, if everyone washed their hands in bleach scrupulously, there would be less demand for firm-led prevention. When these alternatives are available and effective, there is little value in implementing a firm-specific campaign to provide similar services.

Alternative providers of Ebola prevention include the Liberian government, local county governments, and prominent NGOs. Liberian public health has been poor since the late 1970s (Varpilah et al., 2011) and especially since its civil wars (Petit et al. 2013; Ghobarah et al., 2004; and Kruk et al., 2010). While there were 3,526 healthcare workers in 1988, the conflict had reduced this sector by 60 percent, i.e., to 1,396 employees by 1998 (Ali et al., 2015). Recently Liberia health expenditure per capita has remained

consistently lower than other countries in sub-Saharan Africa, and external sources comprise large portions of total expenditures on health. Figure 6 and Figure 7 show this.

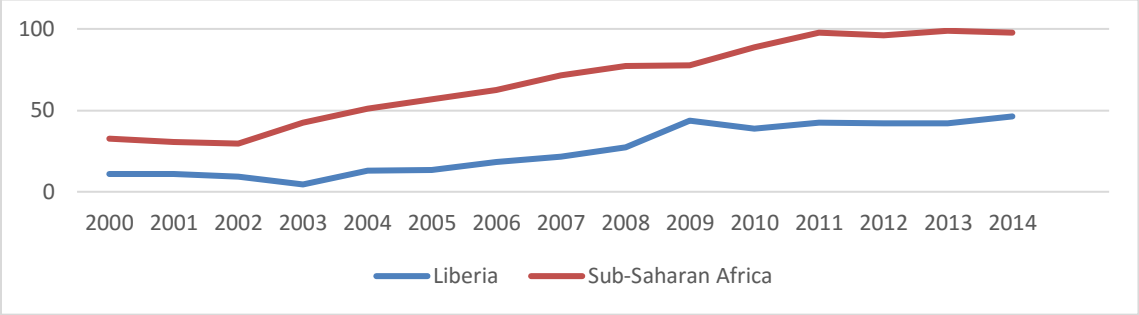


Figure 7. Health Expenditure per capita (current USD), 2000-2014
Source: The World Bank (2016)

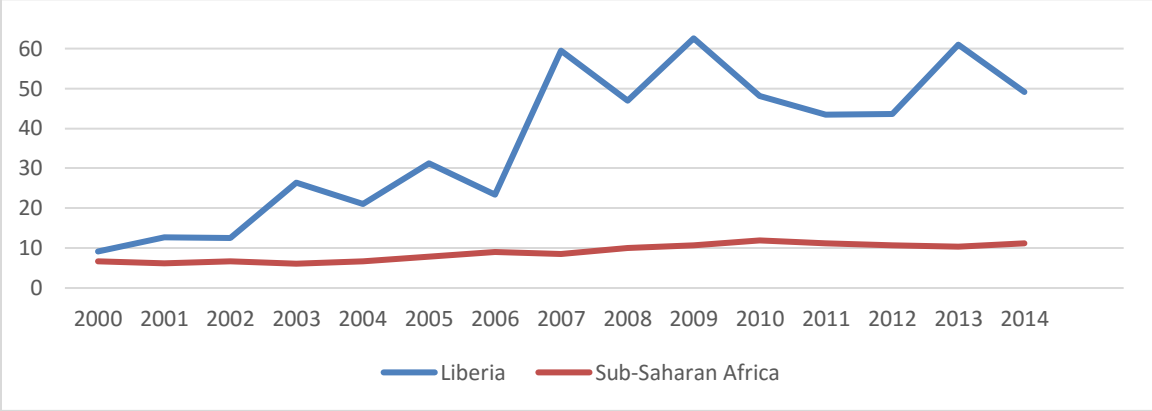


Figure 8. External Health Resources (% of total expenditure on health), 2000-2014
Source: The World Bank (2016)

Recent data also suggests that public health is improving across all regions. Since 2006, maternal health outcomes have improved (MOHSW, 2014: 55-56; Luginaah et al., 2016). Vaccine coverage for children (12 to 23 months) also has increased, from 34 to 48

percent, between 2007 and 2013 (DHS, 2013: 142). The percentage of people living in rural areas with improved sanitation facilities has improved slightly since 2000, while there has been much more improvement in access to improved water sources. Table 4 shows this improvement across regions with additional public health indicators.

Table 6. Measures of Liberian Public Health, by region, 2007-2013

Region	% who have birth certificate	Comprehensive knowledge about HIV		% of women who gave birth in public health facility	% of women informed of pregnancy complications	% of pregnant women with blood sample taken
		Women	Men			
North Western	+28	+22.3	+17	+19	+49.2	+21
South Central*	+17.25	+20.6	+7.35	+10.45	+31.85	+25.4
South Eastern A	+15.8	+19.7	+9.6	+34.6	+30.1	+49.6
South Eastern B	+13.3	+14.1	+5.2	+31.1	+12.2	+68.7
North Central	+25.8	+10.6	-8.6	+16.7	+24.5	+49.6

Sources: 2007 and 2013 Demographic and Health Surveys in Liberia. Numbers denote the change in percentage points, 2007-2013. *****Data from South Central in 2013 includes Monrovia. The numbers for South Central show the change in percentage points between the average of Monrovia and South Central in 2007 and South Central in 2013.

During the epidemic, health services ranged from non-existent to adequate and responsive. As Markel (2014) notes, doctors and healthcare professionals often flee from epidemic disasters. Hospital closures in Liberia were common, mainly owing to inadequate protective supplies, financial support, and healthcare workers (Hinshaw, 2014; Butler, 2014; Summers et al., 2014). While an Ebola emergency task force had been established in some of the counties, none but Grand Bassa had enough resources or the necessary training to provide prevention (Forrester et al., 2014). Improper burials

were common, and operating ambulances were rare (Summers et al., 2014). By December 31, 2014, 370 health workers had been infected; 192 of these survived (MOHSW, 2014).

Some counties did have better public health services during the epidemic (on public health in Montserrado, see Nyenswah et al., 2014). For example, the Bomi County Community Health Department began to monitor the epidemic soon after it was first reported and began to support a 12-bed isolation ward; a second and larger isolation ward was opened in October 2014 (Logan et al., 2014). Furthermore, the public health response in Lofa county – one of the most affected counties – included an Ebola Treatment Unit (ETU), as well as educational and support programs (Sharma et al., 2014).

Hundreds of international humanitarian aid organizations also helped support prevention efforts (Ali et al., 2015; Varpilah et al., 2011). The World Health Organization provided financial assistance, medical training, about 460 public health experts, field laboratories, response teams, logistical support, and research initiatives (WHO, 2015). Gostin (2015), however, notes that the WHO response was delayed because it is underfunded and because of dysfunctional hiring policies that delayed visas and appointments. The UN Mission in Liberia, the UN Mission for Ebola Emergency Response, and the UN Development Program also helped to finance healthcare workers and provide contact surveillance throughout the affected areas. Until September 2014, however, Doctors Without Borders was the leading humanitarian organization responding to the epidemic in West Africa (WHO, 2014).

6 Conclusion

The experiences of privately owned concessionaires in Liberia suggest property rights are an important determinant of firm-led disease prevention. While all firms with concession agreements did not respond to the epidemic, most of the firms who responded had concession agreements and expected to earn profit. Ebola prevention became a vital part of their production processes. Circumstances related to local labor markets and public health alternatives also influenced decisions to prevent Ebola. These conditions and experiences have the following implications.

First, governmental concession agreements encourage firms to develop production plans, maintain the health of workers, and be cognizant of potential epidemiological disasters. Extending existing concession agreements and allowing smaller firms to negotiate similar agreements will give firms in the private sector even stronger incentives to respond. Reforming the bureaucratic administration of property rights and land tenure in Liberia, so that more people have access to well defined and enforced property rights, is an alternative way to give private actors incentives to invest and, when necessary, prevent the spread of infectious diseases. This alternative process of prevention is most appropriate for local and regional outbreaks, but should complement the standard lessons learned from the recent Ebola epidemic, i.e., streamlining the WHO, developing pharmacological remedies, and strengthening international health standards (Gostin, 2016).

Second, behavioral models of epidemiology should consider how people use firms and related private organizations to facilitate disease prevention. If firm-led disease

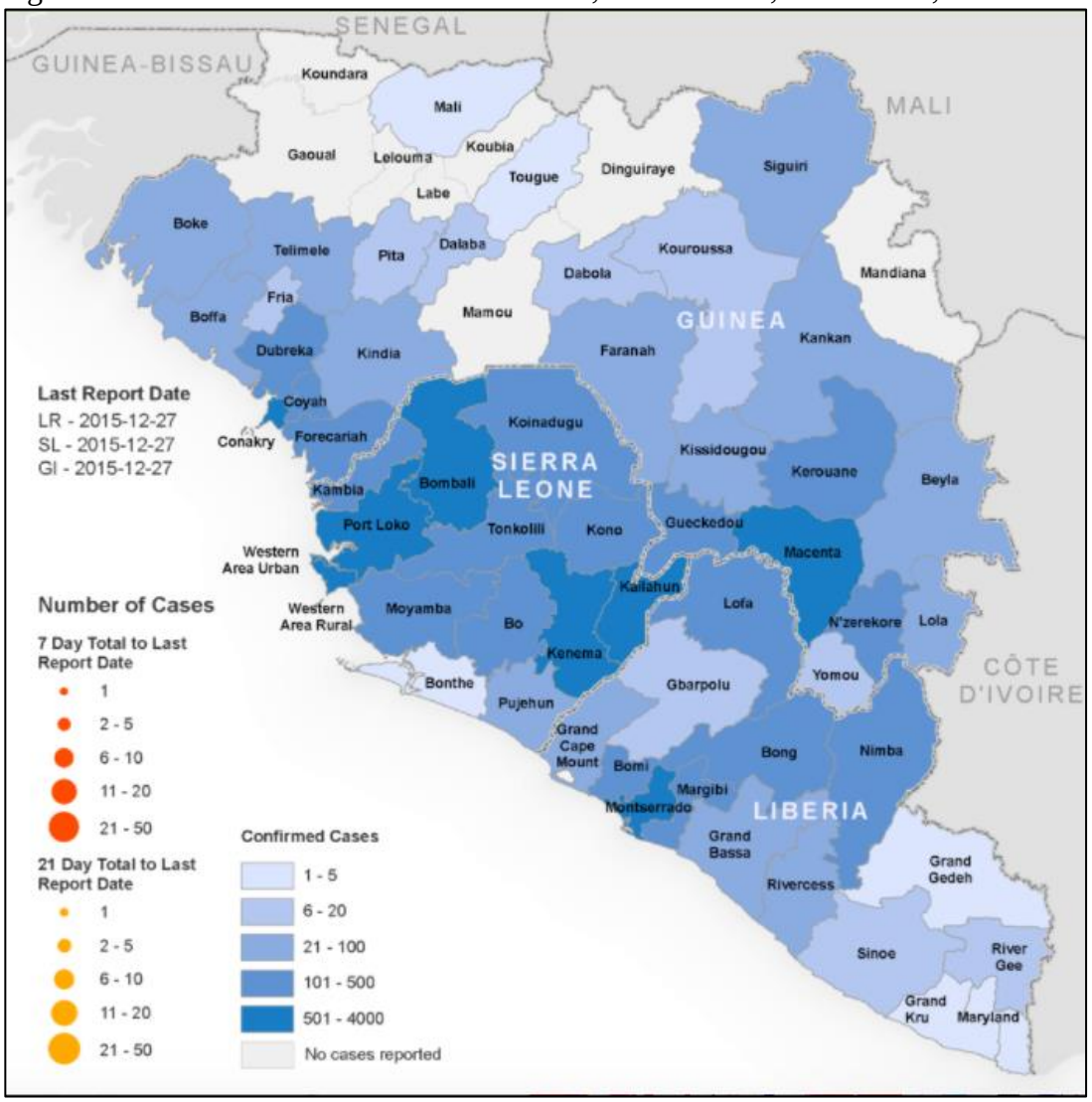
prevention is not considered, models are likely to misrepresent how some people can respond to changes in prevalence rates and are likely to make overly pessimistic predictions. Similarly, the welfare consequences associated with externalities may be overstated, especially when considering how owners, managers, and workers internalize the benefits of prevention. That is, instead of an epidemiological disaster acting upon unresponsive actors and creating private and social costs, private actors can perceive the threat of an epidemic, face incentives for prevention, and discover ways to achieve prevention. While market imperfections may still exist, they are less severe because of the ways in which people responded to the epidemic, particularly because they responded through organizations like the firm.

Finally, firms can be an alternative pathway to provide public goods that may not be provided otherwise. Given Liberia's dysfunctional public health system, the concessionaires saved lives and prevented Ebola's spread. If people live in countries with weak public health services, private firms can coordinate relevant public health experts, medical resources, and common knowledge of how prevention is accomplished in practice. Larger firms also have the ability to finance a prevention campaign or develop better instruments to insure against disasters. Furthermore, firms can be doubly important for public health as they alleviate poverty, a factor of transmission (Fallah et al., 2015) and help to lower the prevalence rates.

APPENDIX I

Ebola

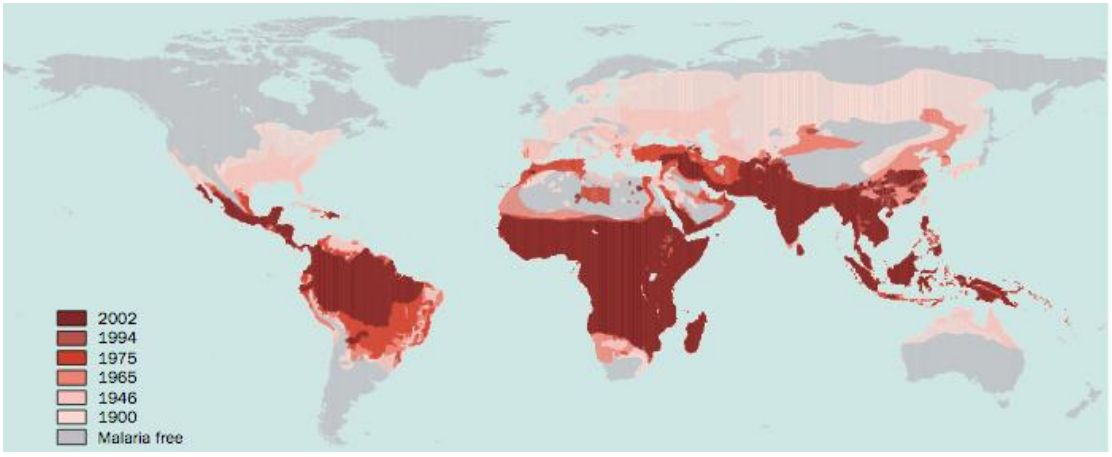
Figure 1. Confirmed Cases of Ebola in Liberia, Sierra Leone, and Guinea, 2014-2015



Source: World Health Organization, Ebola Maps, 2015

Malaria

Figure 2. The Global Burden of Malaria, 1900-2002



Source: Hay et al. (2004).

Table 3. The Global Burden of Malaria, 1900-2010.

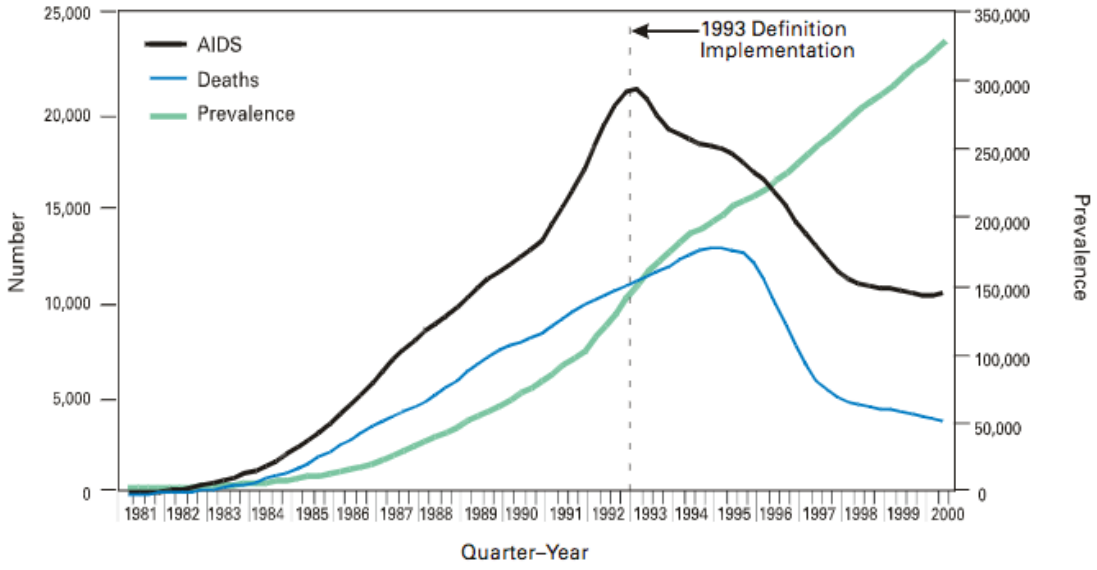
Table 1. Global population at risk from malaria from preintervention to 2010 (~1900–2010)

Time	Global population	Land area malarious		*Countries at risk*	Population exposed	
Years	*n*	*km²*	%	*n*	*n*	%
1900	1 158 409 472	77 594 480	53·16	140	892 373 056	77·03
1946	2 391 400 960	58 565 752	40·12	130	1 635 815 808	68·40
1965	3 363 417 344	53 492 988	36·65	103	1 924 360 320	57·21
1975	4 085 759 488	48 075 780	32·93	91	2 121 086 592	51·91
1992	5 419 255 808	43 650 812	29·90	88	2 565 702 144	47·34
1994	5 582 432 256	39 537 020	27·08	87	2 570 555 136	46·05
2002	6 204 095 488	39 758 172	27·24	88	2 996 419 584	48·30
2010	6 807 085 056	39 758 172	27·24	88	3 410 862 080	50·11

The area totals were generated using the maps of all-cause malaria risk distribution through time (figure 1). The percentage of Earth malarious was calculated from a total global land surface area of 145 975 899 km². To estimate countries at risk territorial designations for 2002 were used throughout (Environmental Systems Research Institute, Inc, Redlands, California, USA). Country-specific "medium variant" population growth rates from the World Population Prospects database (http://esa.un.org/unpp) between 1950 and 2010 were applied to the Gridded Population of the World (GPW) v2.0[31] to generate population distribution maps for 1900, 1946, 1965, 1975, 1992, 1994, and 2002 to match with the malaria risk distribution maps (figure 1) and were also projected to 2010 to enable evaluation of potential future changes in global malaria risk. Global summary counts of these population distribution maps give accuracy to within 5% of the UNDP global population estimate (http://esa.un.org/unpp) for all calculated years. All area and population summaries from these polygons were processed in Idrisi Kilimanjaro (Clark Labs, Clark University, Worcester, MA, USA).

Source: Hay et al. (2004).

Figure 3. Incidence, deaths, and prevalence of AIDS in the United States, 1981-2000



Source: CDC. 2001. "HIV and AIDS – United States, 1981-2000." *Morbidity and Mortality Weekly Report* 50(21), 432.

APPENDIX II

The Firestone Natural Rubber Company

The Firestone Natural Rubber Company of Liberia – located in Margibi County – helped to prevent Ebola within its district during the 2014 epidemic. Among the 20,000-person work force and the Firestone District's total population of 69 to 80 thousand people only seventy-two confirmed cases were reported and eighteen of those patients survived – as of 24 October 2014. This represents a cumulative incidence of 0.09 percent, whereas Margibi County, where the Firestone District is located, is reported to have a cumulative incidence of 0.23 percent (Reaves et al., 2014). Between 1 August and 1 November, 2014, thirty-three Ebola patients died (30 were confirmed); twenty-two confirmed patients survived and were released following stringent symptom-resolution and testing procedures. Overall, thirteen of the twenty-two survivors were Firestone employees or dependents; six were retiree dependents; and three had no connection to Firestone (Arwady et al., 2014).

In an interview with Jason Beaubien (2014), Ed Garcia, the managing director of Firestone Liberia, suggests that the company repurposed its entire management structure to deal with the outbreak. According to the CDC's *Morbidity and Mortality Weekly Report*:

> Firestone implemented administrative and environmental modifications to convert an outpatient health clinic separated from the main hospital to meet the infection control

> standards of an Ebola treatment unit (ETU) following guidance developed by Médecins Sans Frontières. The facility can house 23 patients, including those separated as having confirmed, probable, or suspected Ebola. By April 9, Firestone had completed the construction and certification of its ETU (Reaves et al., 2015: 961).

Patients who were suspected of being infected, like people who shared a house with a confirmed patient, were encouraged voluntarily to enter quarantine in the ETU and in converted schools for twenty-one days. Voluntary quarantine was encouraged for employees and non-employees (Arwady et al., 2014).

Firestone was able to prevent people from entering parts of the district. For example, after health care workers (HCW) experienced high-risk exposures to Ebola in August, Firestone imposed screening and triage rules:

> Firestone established a single, gated access point to the hospital compound that included a screening station staffed by trained HCWs. Screening included temperature readings with noncontact infrared thermometers and verbal responses to a questionnaire about Ebola signs and symptoms irrespective of history of contact with an Ebola patient. Patients with suspected Ebola were sent to the ETU. From August 1 to September 23, three patients were sent to the ETU with suspected Ebola following this screening protocol; one of the three had confirmed Ebola (Reaves et al., 2015: 962).

Suspected infected patients were sorted again based on their conditions: 'Additional triage was conducted to prioritize patients who required hospitalization but were not suspected of having Ebola based on their signs and symptoms. Patients who had some signs or symptoms of Ebola but not those meeting the national Ebola case definition were isolated in a single, dedicated room' (*ibid*: 962). With this sorting mechanism in place, suspected patients were isolated and taken out of the general population. Firestone also helped to reintegrate survivors back into their communities through education programs (Arwady et al., 2014).

Sime Darby Plantation

The Sime Darby Plantation of Liberia (SDPL) – located mainly in Grand Cape Mount, Bomi, Bong, and Gbarpolu counties – helped to prevent Ebola as well. Despite some operational delays in its response, no deaths were reported amongst its workforce of 2,881 (Toweh, 2014; Mokhtar, 2014). The absence of Ebola throughout SDPL stands in contrast to the prevalence of Ebola in its affiliated counties. In a patient database, the WHO reports ninety-six confirmed cases in Grand Cape Mount between 28 July 2014 and 15 Feb. 2015; 132 confirmed cases in Bomi county between 16 June and 1 Feb. 2015; 149 confirmed cases in Bong county between 30 June and 23 Nov. 2014, and twenty confirmed cases in Gbarpolu between 11 Aug and 23 Nov.

Working with local communities, civil society organizations, and county health organizations, SDPL helped to provide medical equipment, food, and relevant sanitation supplies. Regarding its response to the Ebola epidemic in Liberia, SDPL's website states:

> Immediate disaster response was mooted to create Ebola-free workplaces to control the spread of the virus. All estate grounds in Grand Cape Mount and Bomi counties were equipped with necessary personal protective equipment and implemented control measures. Employees and their families were educated on the outbreak, stressing on hygiene and sanitation as well as importance of medical attention. Regular awareness trainings were also conducted with the national Ebola health teams. As a result of the continuous education, no employee or their families living within Sime Darby estates was infected during the outbreak. Sime Darby's clinics on its estates continued to operate and provide medical service to not only its employees but its surrounding communities. Together with the Health Ministry, healthcare was extended despite issues of overcrowding facilities and shortage of medical personnel. (SDPL, 2016)

In a press release issued on October 24, Roslin Azmy Hassan, head of SDPL operations, said, 'Social mobilization efforts like door to door campaigns, are vital to create greater awareness on the virus. SDPL hopes the partnership will overcome some of the challenges faced through greater collaborative efforts with affected communities. SDPL

will continue to work with local players including the authorities and the Government of Liberia in their efforts to contain the outbreak' (SDPL, 2014a).

Sime Darby was particularly helpful in the preventative efforts associated with the villages of Sinje, PAC, and Zodua. SDPL's Social Program Manager, Toushi Itoka, said, 'We were aware of the challenges faced by women, children, and the elderly. We were the only people they could turn to at that time – so we were there for them, as always' (Front Page Africa, 2015). Sime Darby sent medical supplies, fuel, and other sanitation supplies. Sime Darby donated over 700 bags of rice, thermometers, hand washing stations, and chlorine. According to Gabriel Logan, head of the Bomi County Hospital, the Sime Darby clinic was the only referral clinic left open in Bomi. Sime Darby also broadcast radio messages in three languages to help inform people about how the disease spread and ways to prevent it.

Sime Darby also provided humanitarian assistance throughout Liberia. More than five million latex gloves were donated to the Liberian government through a consortium between Sime Darby, the Malaysian government, and other Malaysian companies (SDPL, 2014b; Kennedy, 2014). Matthew Flomo, the Deputy Health Minister for Administration suggested that the gloves would be used across Liberia's fifteen counties to help prevent Ebola's spread. In conjunction with the International Federation of Red Cross and Red Crescent Societies (IFRC) and the Liberian Red Cross (LRC), SDPL helped to finance awareness campaigns which reached over 400,000 people in Liberia. Their work included contact tracing, the extension of healthcare and diagnosis facilities,

training SDPL workers, community engagement, and psychosocial support (Front Page Africa, 2015; SDPL, 2014a; 2014b).

Arcelor Mittal Liberia

Arcelor Mittal (AML) reported three cases and one death during the epidemic across its operations in Grand Bassa and Nimba counties. A patient database of the WHO reports fifty-eight confirmed cases in Grand Bassa county, between 7 July 2014 and 25 January 2015. Nimba county confirmed 114 cases between 30 June and 2 Nov. Arcelor Mittal took a number of actions to help prevent the spread of Ebola and spent more than one and a half million dollars between April and November on prevention (Patrick, 2014).[50] While it halted new projects, it continued its operations in Yekepa and Buchanan. Bill Scotting, Chief Executive of AML, said:

> Clearly the priority for Liberia and other affected countries right now is to contain and ultimately stop this current outbreak of Ebola. We are providing full support to the government in this regard and taking every precaution to protect all of our employees on the ground in Liberia. ArcelorMittal has made a long-term commitment to Liberia and we will maintain this commitment. While the recent developments are very concerning, at present we believe that the emergency procedures and other measures developed and currently in place at all ArcelorMittal sites in Liberia make it possible to continue our phase 1 operations. (AML Press Release, 8 August 2014)

AML's Health and Safety Department organized a discussion and awareness session on 4 April 2014 – well before the epidemic had begun (AML Press Release, 9 April 2014). Professor Adriano Duse, a tropical disease specialist, led the discussion and answered questions about Ebola (Fry, 2014).[51] AML also ordered 500 sets of personal protective equipment to be used by the medical staff of AML, International SOS, Firestone, other

[50] AML originally allocated $3 million to the Ebola effort.
[51] Professor Duse also visited a hospital in the Firestone District.

clinics, and the government hospitals in Sanniquellie and Buchanan. Thermoflash scanners were used to monitor the temperatures of employees and visitors at entry points to all of AML's locations.[52]

In Nimba County, AML provided the health department with its first Ebola treatment unit, which held sixty beds. AML renovated a former eye clinic at the Ganta United Methodist Hospital to build a holding center. AML also constructed an Ebola treatment unit in Sanniquellie at the Harley Hospital in Nimba. Buckets, mattresses and chlorine also were provided by AML (AML Press Release, 16 September 2014).

AML launched an Ebola Contact Tracing and Surveillance program with the help of AFRICARE in the middle of September, 2014. That project, staffed by around 150 people and intended to last until December 2014, provided tracking and monitoring services for local communities in Nimba and Grand Bassa counties. Marcus Wleh, AML's Corporate Responsibility and Government Affairs Manager, said that the project was a 'community based project that builds on local structures to address the critical gaps in contact tracing and surveillance' (AML Press Release, 30 September 2014). The manager of AML operations in Liberia, Ronnie Addy, also suggested that the project would help to increase the participation of local communities.

Other steps in the prevention strategy included the continued employment of Dr. Monia Sayah, an infectious disease expert (AML Press Release, 19 September 2014); the repair and donation of two ambulances to the Liberian government (AML Press Release, 24 September 2014); and site preparation for an Ebola treatment unit, built by the United

[52] Denis Foulds, manager of AML's port operations at Buchanan, suggested that employees probably were safer than people living in the city (Vittozzi, 2014.)

States military (AML Press Release, 30 October 2014). AML was also instrumental in organizing the Ebola Private Sector Mobilization Group, which brought together a number of private and public groups for the purposes of preventing the spread of Ebola (AML Press Release, 17 and 22 Oct. 2014).

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